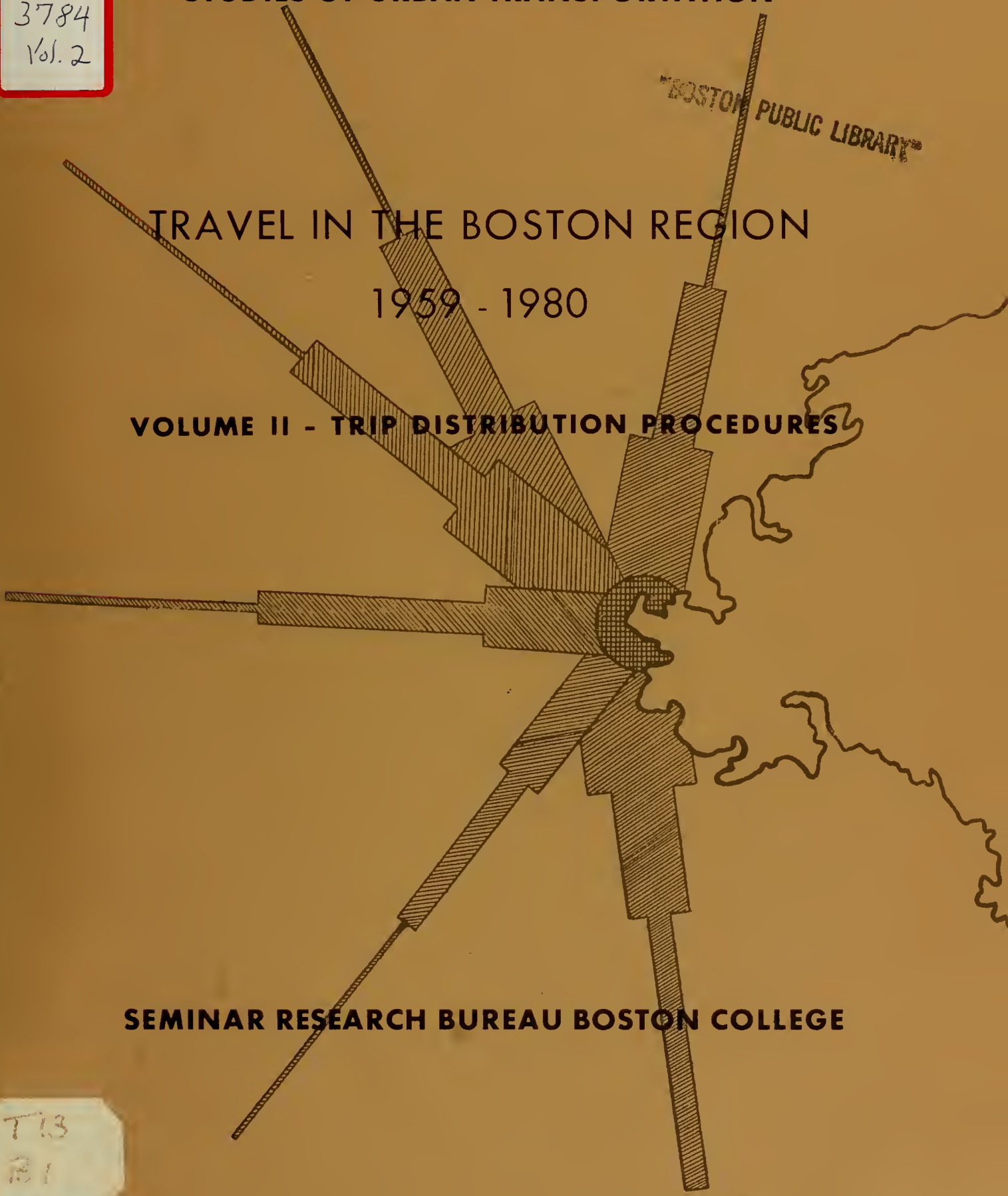
BOSTON PUBLIC LIBRARY
3 9999 06584 028 0
GOVDOC
BRA
3784
Vol. 2
Property of
BOSTON REDEVELOPMENT AUTHORITY
Library
"BOSTON PUBLIC LIBRARY"

STUDIES OF URBAN TRANSPORTATION

TRAVEL IN THE BOSTON REGION

1959 - 1980

VOLUME II - TRIP DISTRIBUTION PROCEDURES



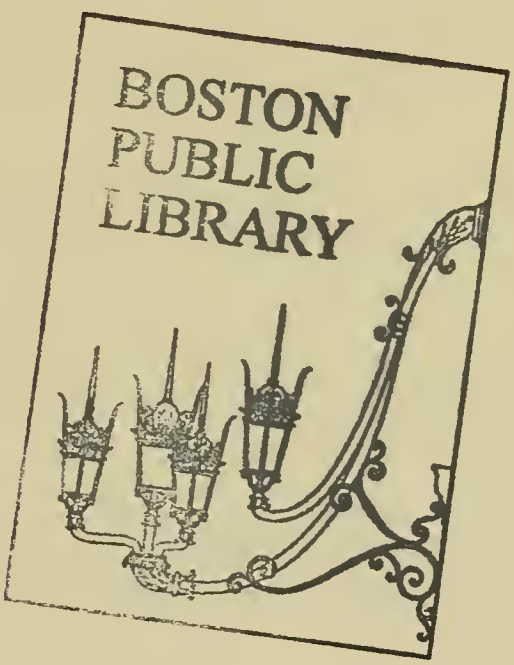
SEMINAR RESEARCH BUREAU BOSTON COLLEGE

T13
R1

STUDIES OF URBAN TRANSPORTATION

TRAVEL IN THE BOSTON REGION
1959 - 1980

VOLUME II - TRIP DISTRIBUTION PROCEDURES



SEMINAR RESEARCH BUREAU BOSTON COLLEGE

February 1961

PREFACE

Transportation analysis and planning begins with the simple and obvious proposition what every trip has an origin and destination. From this premise it goes on to inquire what determines where a trip will begin and end. Further, it inquires as to how many trips originate in a particular place and terminate in other places. Also, it must determine when and how often these trips are made. Again, it must determine what modes are used to make these trips.

When all of these questions have been answered, and the transportation planner or traffic engineer knows the origin, destination, frequency, magnitude and mode of travel for all trips in an area, then and only then, can he translate traffic flows into a comprehensive and intelligent network of transportation facilities which will serve both the present and future needs of the area. This can then be presented to the policy-makers for implementation, in the form of new highways and mass transit facilities.

Since such origin and destination volumes are so essential, it follows that a method must be evolved which will allow their periodic compilation so that accurate and up-to-date figures may be available to those charged with constructing new transportation facilities. Other major metropolitan areas, such as Detroit, Chicago, Washington and Philadelphia have each expended literally millions of dollars for special studies to collect such data on present and future travel habits. In most areas, however, such costs are prohibitive.

At the present time, there are no published, up-to-date figures on traffic volumes or direction on which to base transportation decisions in the Metropolitan Boston Area. It is the purpose of the Seminar Research Bureau in compiling the figures contained herein and in detailing the methods employed in their compilation, to meet this long-felt need in this Area.

STUDIES OF URBAN TRANSPORTATION

BOSTON COLLEGE
Very Reverend Michael P. Walsh, S.J., President

COLLEGE OF BUSINESS ADMINISTRATION
Reverend W. Seavey Joyce, S.J., Dean

SEMINAR RESEARCH BUREAU
Robert J. M. O'Hare, Director

Joseph F. Turley, Former Director

Richard M. Doherty, Assistant Director
Report Editor

Robert G. Davidson, Transportation Associate
Project Director

Anthony J. DiMatteo, Research Assistant
Eugene Calabro, Research Assistant

Dr. John E. VanTassel, Jr., Boston College
Consultant, Sample Design and Data Control

Dr. Joseph D. O'Brien, Boston College
Consultant, Survey Technique and Coordination

Mr. Albert E. Beaton, Harvard University
Consultant, Programing and Data Processing

Mr. Alan M. Voorhees, Automotive Safety Foundation
Consultant, Traffic and Model Analysis

STUDIES OF URBAN TRANSPORTATION

THE BOSTON COLLEGE CITIZEN'S SEMINARS PLANNING COMMITTEE

Very Reverend Michael P. Walsh, S.J.,
Honorary Chairman

John T. Galvin, Chairman

John T. Ahern

O. Kelley Anderson

Ephron Catlin, Jr.

Edward F. Chase

Rev. John J. L. Collins, S.J.

Andrew J. Dazzi

Byron K. Elliott

Thomas J. Galligan, Jr.

Carl J. Gilbert

Ernest Henderson

Donald J. Hurley

Thomas M. Joyce

Rev. W. Seavey Joyce, S.J.

Joseph W. Lund

Sidney R. Rabb

Robert H. Ryan

George Sargent

William A. Schan

Horace Schermerhorn

William H. Sullivan

Donald J. White

Carl F. Woods

Frank J. Zeo

TABLE OF CONTENTS

	Page
PREFACE	ii
INTRODUCTION	1
Premises of the Study	2
THE GRAVITY MODEL	3
Accuracy and Usefulness of the Gravity Model	6
PROCEDURES IN THE APPLICATION OF THE GRAVITY MODEL	8
Determining the Exponents	8
1. The Influence of the Longer Trips	10
2. Variations in Exponent from Zone to Zone	11
Note on Walk Trips	14
INPUT DATA	17
1. Trips Production	17
2. The Attractive Forces	18
3. Distribution of Employment	19
4. Distribution of Retail Employment	23
5. Distribution of Population	28
TRAVEL TIME	41
Terminal Time	45
FINDINGS	48
Exponential Investigation	48
Trip Origin and Destination Tables	55
Note on Accuracy of the Data	88
Tests of the Data	89
CONCLUSION	91
APPENDIX A - Accuracy of the Data	92
APPENDIX B - Use of the Chi-Square	95

MAPS, CHARTS AND TABLES

MAPS		Page
I	Regional Boston	vii
II	Distribution of Total Daily 1959 Person-Trips Originating in Brighton, Brookline and the Fens (Area K)	53
III	Distribution of Total Daily 1959 Person-Trips Originating in the Canton-Stoughton Traffic Area (Area U)	54
IV	The Boston Region - Traffic Zones and Traffic Areas	57

CHARTS

A.	Automobile Trip Travel Time	42
B.	Model Distribution of Work and Non-Work Trips in the Boston Region	50
C.	Accumulated Model Distribution of Work and Non-Work Trips in the Boston Region	52

TABLES

1.	Metropolitan Boston Total Employment, 1959 and 1980	24
2.	Metropolitan Boston Retail Employment, 1959 and 1980	29
3.	Attractive Force for Personal Business Trips in Metropolitan Boston, 1959 and 1980	32
4.	Metropolitan Boston Population, 1959 and 1980	35
5.	Attractive Force for Combined Non-Work Trips in Metropolitan Boston, 1959 and 1980.	38
6.	Terminal Time of Trips in Metropolitan Boston (Minutes)	47

Origin and Destination Tables

7.	1959 Total Daily Person - Trips	58
8.	1980 Total Daily Person - Trips	63
9.	1959 Daily Work Person - Trips	68
10.	1959 Daily Non-Work Person - Trips	72
11.	1980 Daily Work Person - Trips - Alternate #1	76
12.	1980 Daily Non-Work Person - Trips Alternate #1	80
13.	1980 Daily Work Person - Trips - Alternate #2	84

MAP I

REGIONAL BOSTON

100 Cities and Towns

STUDIES OF URBAN TRANSPORTATION

SEMINAR RESEARCH BUREAU BOSTON COLLEGE

February 1961

Digitized by the Internet Archive
in 2011 with funding from
Boston Public Library

http://www.archive.org/details/studiesofurbantr02bost

INTRODUCTION

This report is the second in a series of three dealing with urban transportation in the Metropolitan Boston Region. Their overall purpose is to present the findings of a comprehensive travel survey undertaken by the Seminar Research Bureau of Boston College in late 1958.

The first report[1], which described the techniques and procedures used and presented the initial findings, estimated that total travel in the Region would increase by 55% between 1959 and 1980.[2] The report further stated that most of this increase would occur in the rapidly growing suburbs of Boston. It was also estimated that because of great increases in car ownership, the amount of motor vehicle travel within the region would double by 1980.[3] In other words, twice as many cars will be traveling on the streets and highways of Metropolitan Boston in 1980 than in 1959.

The third report will give the final results of the distribution of origin and destination of the trips and, more importantly, will present the consequent implications for the future highway and transit needs of the entire Metropolitan Area.

The purpose of the present report, which is technical in nature, is three-fold:

1. To describe the detailed procedure and methodology employed by the Seminar Research Bureau in determining the geographic pattern of origins and destinations of trips in the Boston region.

1/ Travel in the Boston Region, 1959-1980, Seminar Research Bureau, Boston College. January, 1960.
2/ Ibid., p.X
3/ Ibid., p.XI

2. To make this detailed analysis available in the hope that appropriate public agencies, both in Metropolitan Boston and in the other major metropolitan areas of the country, will adopt this type of analysis on a continuing basis for transportation planning.
3. To set forth the presumptions and assumptions employed in the study so that users will be able not only to appraise the results more intelligently, but also that they will know why the results are as they are.

Premises of the Study:

To understand fully the study procedure described herein the reader is reminded of the premises adopted at the beginning of this study and still applicable today:

1. That urban transportation, the movement of people within our rapidly growing metropolitan areas, remains one of the greatest unsolved problems of American cities despite the millions of dollars invested in new facilities each year.
2. That the process of finding solutions to urban transportation is as inadequate as the transport problem is real. Despite constant improvements in the science and technology of urban transportation analysis, the process of planning upon the foundations of facts and real needs has much too small an influence upon the process of decision-making and transportation investment and construction.

3. That the process of urban transportation planning and research can lead rather than follow, and can influence decisions and creation of transport policy as soon as these planning processes adopt quicker, better, less expensive and up-to-date methods of fact gathering and analysis.
4. That recognition must be given to the appropriate use of facts as compared to judgment. The end result, the creation of transportation systems, must be the merging of both in proper scale.
5. That the Gravity Model approach to establishing factual knowledge upon which to base transportation policy appears to be a sound technique. (At this date the Bureau of Public Roads of the U. S. Department of Commerce endorses and sponsors studies utilizing the Gravity Model.)
6. That the Boston Metropolitan Area does not now have a unified comprehensive urban transportation policy and program. Nor does it have adequate and up-to-date data upon which to base a policy that will incorporate programs for highways, streets, rapid transit and parking.

THE GRAVITY MODEL

The Gravity Model, mentioned above, is nothing more than a simple formula used to determine how the trips that originate in all parts of the region are distributed. The model is called an Intra-Area Travel Formula by the Bureau of Public Roads. Other Models currently used in other parts of the country have different

names and different characteristics.

All trips must have an origin and a destination. The first report of this series identified how many trips have daily origins in each of the traffic zones of the study. To determine the highway and transit needs, the destinations of all these trips (5,300,000 in 1959; 8,200,000 in 1960) must be estimated. The Gravity Model does this.

The general form of the Gravity Model equation is:

$$T_{(1-2)} = (T_1) \frac{\frac{A_2}{D^x_{(1-2)}}}{\frac{A2}{D^x_{(1-2)}} + \frac{A_3}{D^x_{(1-3)}} + \cdots \frac{A_n}{D^x_{(1-n)}}}$$

where $T_{(1-2)}$ is the daily number of trips from zone 1 to zone 2;

T_1 is the daily number of trips originating in zone 1;

A_2 is the "attractive force"[4] of zone 2;

$D_{(-2)}$ is the distance between zone 1 and 2 (measured in minutes);

x is an exponent whose value depends basically on the purpose of the trips being distributed.

$D^x_{(1-2)}$ is the "friction force" of travel (comprising distance, time and congestion) that works to minimize the length of trips in accordance with human behavior.

Thus, the Gravity Model distributes the total trips from any zone to all other zones in accordance with the number of trips originating in the zone, the attractive forces of other zones, and the friction

---

4/ See page 18 for the definition of the several attractive forces.

forces between the originating zones and the zones of destination.

A number of assumptions are implicit in the use of the Gravity Model:

1. In every group of people there are some who will make long daily trips and some who will make trips of moderate length. But the majority will make short daily trips.
2. Each group of people is similar in this regard to all other groups, regardless of where they live.
3. This human behavior pattern must be adjusted to recognize that in all cases the average length of trip is also influenced by the closeness or remoteness of the attractive forces which cause the trips to occur.

To illustrate, let us take two zones of equal population, A and B. Zone A is a densely populated, low-income section of corporate Boston located but a few miles from the Downtown Area. Zone B is a medium-high income suburb located about 20 miles from Downtown.

The model basically assumes that the people in Zone A will make as many long trips as people in Zone B. However, it modifies this assumption by further assuming that trips by people in Zone A will be affected by the greater number of attractive forces in close proximity which fill the needs of Zone A travelers. Therefore, since the residents of Zone A have a greater number of potential destinations nearby than do residents of Zone B, the Model will assign many short trips and few (if any) long trips to residents of Zone A. Conversely, it will assign many long trips and few short trips to residents of Zone B.

Accuracy and Usefulness of the Gravity Model

Because the model applies an "average" travel pattern to all zones in the region, certain errors are bound to occur. The model will assign a heavy proportion of work trips from one zone to a number of jobs nearby. The actual case may be that the residents that make these trips are white collar workers while the jobs may be filled by laborers. A specific example would be the assignment of trips from the high-income suburbs of Weaton and Wellesley to fill the semi-skilled jobs along nearby Route 128. In actuality a large share of the travelers from Weston and Wellesley go Downtown to office buildings.5/

The similar misapplication of a general formula to specific groups of people will be recognized as weaknesses of the Gravity Model approach. But inconveniences caused by this type of condition are isolated and insignificant in magnitude when compared to the total results of accumulated traffic flows.

Actually, much larger errors are inherent in other methods of traffic forecasting. Forecasting population quantities and distribution throughout the region can cause much greater errors. Estimates of the distribution of jobs that attract work trips can cause other errors that surpass the significance of errors of the mechanics of the model itself. That this condition is true is borne out in later discussion.

The point is that in creating facts and values for the formulation of major policy, the model provides data that is sufficiently

---

5/ For example, a recent study of one of Boston's high-income suburbs in close proximity to Route 128 showed that less than 20% of the daily work trips from the town had Route 128 as a destination. Greater Boston Economic Study Committee. Economic Base Report #8. October, 1960. p. 24.

adequate and accurate to establish the need and priority of major facilities such as expressways, major highways and rapid transit routes. In addition, it provides information essential to policy formulation in regard to basic land use and zoning requirements.

The results of the Gravity Model are neither intended nor designed to aid in locating or designing minor facilities, such as a ramp to an expressway. It is the belief of the Seminar Research Bureau that no comprehensive Origin and Destination survey can go beyond suggesting that a certain number of ramps will be required in 1980. To be sure, comprehensive traffic data may be able to help in the locating of such facilities as ramps. But more important factors in this regard are the design of the local street system and the economics of land takings.

PROCEDURES IN THE APPLICATION OF THE GRAVITY MODEL

One of the most important variables in the Gravity Model equation is the "friction factor" - defined as the time (in minutes) required to travel between any two zones, raised to an exponent. In prior studies, it was found that the magnitude of this exponent varied according to purpose of trip; i.e., work trip, shopping trip, social trip, etc. It was necessary, therefore, to determine the value of such exponents for trips in the Boston Metropolitan Area in order to carry out the calculations with the Gravity Model.6/

A program was devised to test a series of exponents for the various kinds of trips, and to compare the results with the actual data obtained in the home-to-home interviews conducted by Boston College and described in the first report. The exponents that were finally selected were those which give the least variation between the model results and the actual data obtained.

The procedure used and the results obtained are set forth in the following sections.

Determining the Exponents

In the first instance, calculations were made for a series of exponents for each of the major trip purpose categories: 1. work trips; 2. shopping trips; 3. social, civic, educational and religious trips; and 4. personal business, business related to work, and recreation trips. These groupings of trips are the same as those reported on in the first report. They were so grouped because of previous indications that their travel length characteristics and attractive forces were similar.

6/ Most of the calculations were carried out on the IBM 704 Computer at M.I.T.

Calculations of the number of trips from the ten interviewed zones to all other zones were completed for a number of exponential values. These values were preselected to range around that value most expected to be true for the Boston Region (in view of the nature of the input). For work trips the values ranged from 1.5 to 3.0 at .5 intervals. For shopping trips, social trips and personal business trips, the values were higher, ranging from 2.0 to 4.0. But for reasons described below all calculations for the non-work categories were not carried out to completion at this time.

To determine the amount of variability between the model estimates and actual origins and destinations, a simple chi-square test was used.[7/] The test was made in such a manner that both the variation for each zone, and the total variation for all ten zones combined was identified.

The results from this first test proved unsatisfactory. While the amount of variation between actual and estimated values was relatively small, the pattern of improvement of chi-square values as alternative exponents were substituted was too weak. In other words, the improvement in the test values was not strong enough so that any one exponential value could be confidently employed in the expansion of the actual sample results.

On re-examination of the process of calculation, it waa found that two influences were biasing the chi-square test:

---- There was too great a difference between the actual and estimated number of those trips which went to the more remote zones;

7/ A brief description of the chi-square test is given in Appendix B.

---- It appeared that the value of the exponent varied not only by trip purpose, but also from zone to zone. This, it was discovered, was due to the omission of "walk trips" from the calculations.

1. The Influence of the Longer Trips

The cause of the bias in the origin and destination pattern for longer trips was found to be the manner in which the sample data was used.

The actual data which was used to test the accuracy of the estimates was based on a sample of 100 families in each of the ten traffic zones. The sample size, then, was one-eighth of one percent (0.12%) of all families in the Metropolitan area. The sample size in each of the ten zones varied between 0.37% and 2.09% of the families in each. In all, the survey counted 6500 trips, an average of 650 in each zone.

The model origin and destination estimates, on the other hand, pertained to 100% of the families in the area, so that to compare actual and estimated travel patterns, the sample results had to be expanded to the 100% level.8/ The effect, then, was an expansion of each actual trip by a factor of between 50 and 300. This expansion caused no serious bias in the great amount of short trips to adjacent zones. However, in those instances where the sample "actual" data showed only one trip to a remote zone, the expansion caused this "actual" number to become 50 or more (up to 300). Yet an adjacent remote zone would be receiving no trips. This situation would be very unlikely, and would, of course, cause the chi-square test to indicate a very great amount of variation, thereby distort-

8/ Or, Conversely, the model results had to be reduced to the level of the sample data.

ing the validity of the test (when compared to only a few trips distributed by the model.)

The more likely situation is that a total of some 50 (or more) trips are actually distributed from an originating zone to a group of remote zones of destination, and not to just one to the exclusion of all others adjacent or near to it.

As a result of the adverse influence these long trips had upon the test, another method of test evaluation was devised. Instead of determining the chi-square value of the difference between "actual" and estimated trips for each destination zone, the values were determined for successive five minute rings emanating from each of the ten zones. In this way, the enormous biasing influence upon the test of a remote zone was neutralized by the inclusion of data for all zones at the same distance, measured in travel time minutes. This proved a much more satisfactory method of testing the differences between actual and estimated trips. The chi-square values which resulted proved much more satisfactory.

The longer trips still influence the value of the chi-square test but less so than under the previous method described above. Furthermore, by grouping the actual trips for the four 5-minute categories over 50 minutes, and comparing them with the estimated trips in these categories, the influence of the longer trips becomes slight.

2. Variations In Exponent from Zone to Zone

The initial results suggested that each zone seemed to have a different exponent. The methods were revised, therefore, so that the chi-square test could be completely analyzed for each individual originating zone for which "actual" trip data existed, as well as for the entire ten zone total.

The equation was computed for the 10 traffic zones. The chi-square test proved much more reliable and stronger. The calculations were completed as before, for work, shopping, social and personal business trips. Various exponents were used until the lowest chi-square value was determined for each zone. The exponents tried ranged from 2.0 to 4.5 for work trips, and from 2.5 to 5.5 for the three non-work purposes.

The results proved useful and interesting. First, the strong adverse influence of the longer trips became neutralized to a great extent; secondly, an evaluation of the cause of different exponents could be analyzed in the case of each town.

The results show that lower values of exponents better fit the travel patterns of residents of the inner group of traffic zones included in the survey (the Fens area, Cambridge, Dorchester), and higher exponents best fit the travel in the outer suburbs (Stoneham and Needham-Dover). The best exponent for the Fens area for work trips proved to be about 2.25. The best exponent for an outer suburb, Stoneham, for work trips was found to be about 3.5 or 4.0.

A similar condition proved to be the case for the non-work trips. Lower values of the exponent more accurately fitted the trip pattern for the inner zones and higher values for the outer zones. In the case of each of the non-work trip purpose categories, the most accurate exponential values tended to be higher than that for work trips. The values for shopping trips ranged from 3.5 to 5.5; for social trips, from 3.5 to 4.5; for personal business trips, from 2.5 to 4.5.

The exponential values derived for trips in the non-work category proved to be less than satisfactory. This was particularly true of personal business trips and was due to the fact that the

number of "actual" trips determined by the sample were too few in number to serve as an adequate basis. Because of this fact and the general similarity between the apparent "best" values for each of the non-work categories, a total non-work computation was made incorporating shopping, social and personal business trips. The chi-square test of this non-work computation proved better because of the greater sample of actual trips available in the composite. The exponents proved to be between 3.75 (in the inner communities) and 5.5 (in the outer communities.) The results were so much more satisfactory and reliable for the composite non-work calculations that this grouping has been retained throughout the remainder of the analysis.9/

Further analysis indicated that the inner zones (which appeared to have a lower exponential value) were in error when the larger exponents were used because of the differences between actual and estimated trips at the shorter distances. In other words, the higher value exponents more accurate for the intermediate and outer zones, consistently distributed a greater number of short estimated trips than was found to be the case described by actual results (as a result, too few trips were distributed to intermediate and longer distances.)

This difficulty was identified as resulting from the greater number of walk trips occurring in the more densely developed inner zones than in the outer zones. To investigate this possibility, the number of walk trips to work occurring in each of the ten zones (as determined from the home survey) were added to the number of

---

9/It had been our intent originally to use this composite non-work trip category because other studies have shown it to be more reliable than the individual categories. We decided, however, to at least explore the results of using the individual non-work trip categories.

"actual" trips occurring in the 0-10 and 10-15 minute time zones.[10/]

Adding in the number of walk trips, a chi-square test was computed for the work trip analysis for each zone and for all zones at the higher levels. The process of accounting for walk trips indicated that the variation in best exponential values for each zone was no longer valid. In fact, the results proved good enough to justify use of that exponent finally selected. It is to be quickly added that the resultant chi-square test with walk trips added did not indicate that the best exponent for each zone was in all cases exactly the same number. The variation was greatly reduced and it can be stated that the remaining variation is unbiased, non-significant and, in fact, a product of the physical and economic patterns of each of the ten zones analyzed.

Note on Walk Trips

The Seminar Research Bureau considers this rather obvious, but not heretofore utilized influence, of major significance, and believes that it will serve to make the usefulness of Gravity Model traffic analysis greater. The significance of walk trips strongly suggests that future origin and destination surveys that utilize even a small sample should attempt to count the number of walk trips for various purposes.

This presents a problem in itself of prescribing what is to constitute a trip. In the case of work trips a movement from place of living to place of employment - whether on foot or in a vehicle - is not a difficult incident to identify and count. But non-work purposes are more complex, for heretofore the definition of a trip

10/ These walk trips were expanded to account for the sample size, and all other actual trips in all of the five minute travel time zones were adjusted for the new expansion factor.

was that which took place in a vehicle. Does the walk to the corner for a loaf of bread constitute a trip? If so, is the walk to an adjacent house for neighborly conversation a trip? And if so, is the walk to the garage for a household chore a trip? Quite obviously there is a difficulty of definition that deserves classification before a standard process can be worked out.

The difficulty lies in the difference of travel patterns between the suburbanite and the cliff dweller. The suburbanite might well jump into the car for an hour's visit with a friend. The cliff dweller may visit just as close a friend by staying in the same building or walking no further than a block.

Perhaps it is true that all typical families (or groups thereof) undertake about the same number of the same kind of trips per day or per week. The question is how: on foot or in a vehicle?

This analysis faced this real problem when it came to non-work trips. The same problem as in work trips existed for these trips and had to be adjusted for. Unfortunately, the survey did not provide "actual" data on walking trips for social, shopping or personal business purposes. An estimate was made. The only available data to use as a basis was the pattern of walk-to-work trips.

The walk-to-work trips were analyzed and seemed to be most strongly related to housing density, type of housing structure, distance from Downtown Boston, and the ratio of car ownership. Enough data existed to make a firm statistical relationship. The pattern was clear enough to show that an adjustment made on this basis was much more correct than no adjustment at all. Therefore, the number of non-work trips was adjusted to include walk trips in each of the ten zones in the same proportion as in walk-to-work trips.

In the case of the Fens Area this increased the number of trips by 50%. The remaining zones received increases ranging from 50% down to 0. Cambridge was increased by 20%; Dorchester by 10%. Stoneham was not increased at all.

As in the case of work trips, the chi-square values became lowest for all zones at higher values and the results looked statistically useable. The adding of some estimated walk trips did not completely eliminate variation from one zone to another but the variation that remains is undoubtedly significant and influenced heavily by the travel patterns peculiar to that zone.

As a result of the substantial improvement created by adding walking trips into the total number of trips generated by the ten zones, the exponents could be much more strongly identified as 3.5 for work trips and 5.0 for non-work trips. These were selected and used in all the final computations. Estimates of the numbers of walk trips for work and non-work purposes were made and included. The estimates were made primarily on the basis of current and future car ownership. Thus, a zone with a low car ownership (like the Fens) was assigned a greater number of walk trips.

After the final calculations were made, these walk trips were subtracted out again to leave only those trips undertaken in vehicles. In all cases the walk trips were subtracted out of the shorter trip length categories - for the most part from intra-area trip totals.

INPUT DATA

The input data values inserted into the Gravity Model include four factors: estimated 1959 and 1980 population and its distribution, estimated distribution of employment, car ownership characteristics, and measures of travel time. In many respects, the forecasts of 1980 travel on the highways of Metropolitan Boston are more greatly influenced by these factors than they are by the other characteristics of the gravity model equation.

It is recognized at this point that no two professional persons will make exactly the same estimates of these 1980 population and economic factors. Every available source of good information has been reviewed. The estimates are to the best of our knowledge and ability moderate yet optimistic projections of recent trends in the Boston Metropolitan Area, conditioned by expected national and international influences and the personal judgment of the staff of the Seminar Research Bureau and experts throughout the region.

1. Trip Production

Trip production (the T factor in the equation) is the number of daily trips originating at the home, in each traffic zone. These values are the same as shown in report #1 adjusted upwards for walk trips as explained above.

Therefore, the model computations derive only one-directional home-based trips. The return trip from the original destination back to the home is an equal amount of trips in the reverse direction. The origins and destinations of non-home based trips were not calculated with the Gravity Model because of the great uncertainty of

trip production and attractive forces in each zone. These trips will be accounted for in Report #3.

2. The Attractive Force

The attractive force (the "A" factor in the model equation) differs according to the reason for undertaking the trip. The force that induces a work trip, for example, is entirely different from that which induces a trip to the theater. Thus, it was necessary to determine and quantify these different forces for purposes of the equation. The forces selected for use are set out below.

a. Work Trips

Since the number of jobs in a zone will attract an equal number of work trips to that zone, the attractive force for work trips was taken to be the estimated total employment in each traffic zone for 1959 and 1980.

b. Shopping Trips

For shopping trips, the attractive force was taken as the estimated number of retail employees in each traffic zone in 1959 and 1980.

c. Social, Civic, Religious and Educational Trips

For these trips, the most useful attractor was found to be the estimated population in each zone for 1959 and 1980.

d. Personal Business and Recreational Trips

Studies similar to this one in other areas have shown that the attractive force for this type of trip is some combination of retail employment and total employment. For the Boston area, it was determined that the best combination of these factors is total employment plus five times retail employment.

e. Total Non-Work Trips (b + c + d, above)

For total non-work trips, the attractive force used was a combination of the three non-work attractors, with the attractor for each individual purpose weighted according to the average number of trips expected to occur for each of the purposes in 1959 and 1980. Mathematically, this turns out to be: 17.5 times retail employment plus twice total employment plus population.

It should be noted here that the absolute values of the attractor are important only in the case of work trips, where there is a high correlation of number of trips and total employment. However, since there is no equally useable check on the number of non-work trips to a given zone, the absolute value of any non-work attractor is no better than a good relative attractor. Since the model, if fact, distributes trips proportionally, the non-work attractors are adequate for purposes of Origin and Destination computations.

3. Distribution of Employment

a. Employment in 1959

In distributing 1959 employment, the basic data utilized was that published by the Massachusetts Division of Employment Security. This information, already broken down by city and town, required two adjustments, however.

First, since certain types of employment are not covered,[11] and hence, not reported, this employment had to be estimated and incorporated. Our studies showed that this increase amounted to

11/ Agricultural workers, domestics, railroad employees, employees of non-profit organizations, state, county and municipal employees, and self-employed workers are not covered by D.E.S.

approximately 20% of covered employment, and we therefore have used this factor in all computations relating to employment.

Secondly, in some cases, a traffic zone constituted only a part of a city or town. In such cases, the data had to be adjusted to reflect the zonal size and location. Cambridge and Somerville, for example, were each divided into two zones, based on the amount of land in each zone currently used for commercial and industrial purposes. The city-wide data was then adjusted accordingly.

The determination of total employment in each of the fourteen sections of the City of Boston was accomplished by a special study which incorporated an analysis of many reports on employment in the city and judgments as to the location of workers not covered by Employment Security.12/

b. Employment in 1980

It has been assumed that a 20% increase in population by 1980 will be accompanied by a 20% rise in the total number of jobs available at that time. This presumes, of course, that the same proportion of the population will be in the labor force. Thus, the 1,000,000 jobs in the region in 1959 will expand to approximately 1,200,000 by 1980.

Distributing these additional 200,000 jobs throughout the region, however, is difficult at the least. There is no prescribed method that will insure an accurate distribution. Compounding the difficulty is the acknowledged fact that new transport facilities

---

12/ Prepared by John Culp, formerly Research Associate with the Greater Boston Economic Study Committee.

(highways and transit routes) are a significant influence on the location of new job-creating commercial and industrial developments.

Also to be considered are two opposing theories of commercial and industrial development. The decentralization theorists maintain that industry will be dispersed throughout the entire Metropolitan Area, rather than concentrated in any particular part of the Area. Conversely, there are those who contend that the Downtown area will be rejuvenated and that business and industry will be concentrated in and around Downtown.13/

To meet both of these possibilities of future economic development, alternative methods of employment distribution were devised. Both alternatives utilize a basic regional job distribution whereby the 1980 employment in each city or town (or traffic zone) increases or decreases according to two influences: the ratio of 1980 to 1959 zonal population, and the ratio of 1980 and 1959 total metropolitan employment.

13/ Others feel, perhaps justifiably, that a study such as this should determine where jobs can be best located, in terms of traffic and transportation needs. They maintain that transportation facilities should be a cause of desired job and living locations, not an effect.

With additional time and funds, perhaps this study could determine the "best" location of homes and jobs in order to minimize costs of transportation facilities. However, lacking both time and funds, we must confine our objectives to describing the implications for transportation requirements of a continuation of current regional development trends. Careful analysis of the results will provide warning signals that certain types of uncontrolled regional development can do much harm or cause substantially greater highway costs.

Thus, estimated employment in 1980 in any zone was determined by the formula:

$$E_{1980} = E_{1959} \left(\frac{\frac{P_{1980}}{P_{1959}} + 1.20}{2} \right)$$

where E_{1980} is the employment in the zone in 1980

E_{1959} is the employment in the zone in 1959

P_{1980} is the population of the zone in 1980

P_{1959} is the population of the zone in 1959.

Under this method, a zone that experiences a 40% increase in population will have an increase in employment of 30%. On the other hand, a zone experiencing a decrease to 80% of its current population will have no resultant increase or decrease in employment. Admittedly this a rough procedure for estimating the distribution of employment. But its limitations are not such as to destroy the usefulness of its results.

Having determined that this formula would provide an adequate distribution of employment, we then used it for two alternative computations.

In both alternatives, the same increase in employment between 1959 and 1980 - some 200,000 - is foreseen. The two alternatives, however, distribute this increase in different ways.

The first alternative, which accords with the theory of increased economic activity in Downtown Boston, allows the normal increase in employment (according to the formula above) to the group of communities along Route 128, but doubles the expected increase (18,000) in employment for Downtown Boston. Thus, Boston's employment is expected to increase by some 36,000.

The second alternative, which accords with the decentralization theory, gives but the normal increase in employment to Downtown (18,000), and allots 18,000 more jobs than normal to the Route 128 communities.

It should be noted that in both cases the Seminar Research Bureau is optimistic about the economic prospects for Downtown Boston. Both alternatives call for increased employment and the only question is as to the amount of increase. It is felt that Downtown will experience an increase in employment, given reasonable transportation and taxation policies.

These estimates do not, however, suggest that Downtown Boston will experience job increases as large as the other parts of the region. Taken as a whole the number of jobs in the region should increase by 20% while those in Downtown will increase by between 7 and 15%. However, Downtown Boston is a center for "primary" or regional economic activity and employment. Thus, Downtown Boston is expected to receive its share of that type of basic economic development and employment to which it is best suited.

Table # 1 shows the resulting distribution of jobs for each alternative estimated for 1959 and 1980 in each city and town. These values were used in the gravity model calculations.

4. Distribution of Retail Employment

In order to distribute shopping trips, it was necessary to estimate the magnitude of its attractor -- retail employment -- in each zone for 1959 and 1980.

STUDIES OF URBAN TRANSPORTATION

Table # 1 Seminar Research Bureau

METROPOLITAN BOSTON TOTAL EMPLOYMENT, 1959 and 1980

Distribution by 100 Cities and Towns (Traffic Zones)

Sector I - Northeast		Total Employment		
		1959	1980	
ZONE	MUNICIPALITY		Alternate #1	Alternate #2
101	East Boston	8,000	8,700	8,700
102	Winthrop	1,000	1,200	1,200
103	Chelsea	11,200	12,000	12,000
104	Revere	4,700	5,700	5,700
105	Saugus	2,400	3,300	3,300
106	Lynn A	17,000	18,300	18,300
107	Lynn B, Nahant	38,200	41,200	41,200
108	Swampscott Marblehead	2,700	3,800	3,800
109	Salem	15,900	18,400	18,400
110	Peabody	9,500	13,400	14,400
111	Lynnfield	800	1,400	2,400
112	Danvers Topsfield Middleton	8,100	13,100	13,100
113	Beverly	9,500	12,200	12,200
114	Hamilton Wenham, Essex Ipswich Manchester	2,900	4,200	4,200
115	Gloucester Rockport	8,100	10,000	10,000
Sector I - Total		140,100	166,900	168,900
Sector II - Northwest				
201	Charlestown	20,100	19,000	19,000
202	Cambridge A	30,000	32,900	32,900
203	Cambridge B	48,000	52,700	52,700
204	Somerville A	5,000	5,500	5,500
205	Somerville B	20,000	21,900	21,900
206	Everett	15,900	17,900	17,900
207	Malden	16,800	19,700	19,700
208	Medford	10,700	12,000	12,000
209	Arlington	4,500	5,800	5,800
210	Belmont	2,600	3,200	3,200
211	Lexington	3,000	4,700	5,700
212	Winchester	3,400	4,700	4,700
213	Stoneham	2,600	3,800	3,800

Table # 1 (continued)

ZONE	MUNICIPALITY	Total Employment 1959	1980 Alternate #1	1980 Alternate #2
214	Melrose	5,700	7,500	7,500
215	Wakefield	5,100	6,800	7,800
216	Reading	2,100	3,200	4,200
217	Woburn	6,500	9,000	10,000
218	Lincoln, Acton Carlisle, Concord	5,400	8,000	9,000
219	Burlington Bedford	5,300	12,300	13,300
220	N. Reading Wilmington	1,600	2,300	2,300
Sector II - Total		214,300	252,900	258,900
Sector III - West				
301	Fens	26,800	29,100	29,100
302	Brighton	16,300	17,900	17,900
303	Brookline	12,400	15,300	15,300
304	Newton	25,000	30,000	31,000
305	Watertown	19,300	23,300	23,300
306	Waltham	33,000	43,300	44,300
307	Weston, Wayland	3,500	6,300	7,300
308	Wellesley	4,800	6,000	6,000
309	Needham, Dover	8,300	13,300	13,300
310	Natick	4,500	6,700	6,700
311	Sherborn Holliston Ashland	4,000	7,000	7,000
312	Framingham	18,500	27,100	27,100
313	Sudbury, Maynard	4,300	5,900	5,900
Sector III Total		180,700	231,200	234,200
Sector IV - Southwest				
402	Roxbury A	13,100	13,600	13,600
403	Roxbury B	13,100	13,700	13,700
404	Jamaica Plain	8,500	9,400	9,400
405	Roslindale	3,400	3,800	3,800
406	W. Roxbury	3,100	3,700	
407	Hyde Park	7,600	8,600	
408	Dedham	5,600	6,900	7,900
409	Westwood	1,000	1,800	2,800
410	Norwood	9,200	13,000	13,000
411	Walpole, Sharon	5,600	7,700	7,700
412	Medfield, Millis Norfolk, Medway	1,900	3,100	3,100
413	Foxboro Mansfield	5,800	8,300	8,300
Sector IV Total		77,900	93,600	95,600

Table # 1 (continued)

ZONE	MUNICIPALITY	Total Employment 1959	1980 Alternate #1	1980 Alternate #2
501	South Boston	26,200	27,700	27,700
502	Dorchester A	3,000	3,300	3,300
503	Dorchester B	3,000	3,300	3,300
504	Dorchester C	5,000	5,600	5,600
505	Dorchester D	10,000	10,900	10,900
506	Milton	1,600	2,300	3,300
507	Quincy	37,400	44,100	45,100
508	Canton, Avon Stoughton	7,400	11,100	12,100
509	Randolph Holbrook	2,600	3,500	4,500
510	Braintree	5,700	7,900	8,900
511	Weymouth	4,900	6,800	6,800
512	Hingham, Hull Cohasset	3,400	5,600	5,600
513	Scituate, Norwell Marshfield	1,800	3,300	3,300
514	Hanover Rockland Abington Whitman	9,600	13,000	13,000
515	Brockton	26,000	28,800	28,800
516	Easton W. Bridgewater	1,500	1,900	1,900
517	E. Bridgewater	3,300	4,300	4,300
518	Hanson, Pembrook Duxbury	1,600	2,400	2,400
Sector V - Total		154,200	185,800	190,800
000-5 Downtown		243,000	279,000	261,000
Grand Total		1,010,200	1,209,400	1,209,400

a. Retail Employment in 1959

The figures used for 1959 retail employment in each zone were those published in the 1958 Census of Business.[14] These figures required only one adjustment, and that was in order to distribute total retail employment for Boston to the individual zones comprising Boston.

This distribution was made on the basis of population. Thus, it was assumed that retail employment in each individual zone bore the same proportion to total retail employment in Boston as a whole as the population of the zone bore to the total population of Boston. For example, East Boston (zone 101), contains 11% of Boston's 1959 population. Therefore, 11% of Boston's total retail employment was alloted to East Boston.

b. Retail Employment in 1980

To project retail employment to 1980, the data from the 1958 Census of Business was used as a base. The retail employment in each zone was then expanded by using this modified version of the formula on page 22 employed to forecast total employment:

$$RE_{1980} = \frac{(RE_{1959})\left(\frac{P_{1980}}{P_{1959}}\right) + 1.20}{2}$$

where RE_{1980} is the retail employment in the zone in 1980

RE_{1959} is the retail employment in the zone in 1959

P_{1980} is the population of the zone in 1980

P_{1959} is the population of the zone in 1959

14/ U. S. Department of Commerce, Bureau of the Census. 1958 Census of Business: Retail Trade - Preliminary Area Report-Massachusetts

This formula, like the previous one, incorporates the 20% growth expected to occur in the Boston Region, and also takes the expected population growth into consideration.

The resulting distribution of retail employment by zones in 1959 and 1980 is shown in Table 2 .

5. Distribution of Population

The attractive force for social, civic, educational and religious trips is population. These population estimates for 1959 and 1980 were presented in the first report[15/] but for easy reference are reproduced here in Table 4 .

Utilizing the estimates of population, total employment and retail employment, the magnitude of the attractive forces for (1) personal business trips, (2) social, civic, educational and religious trips, and (3) combined non-work trips, was computed. These magnitudes, by zone, are set out in Tables 3 , 4 , and 5 .

15/ See: Travel in the Boston Region, op. cit., pp. 86-88

STUDIES OF URBAN TRANSPORTATION

Table # 2

Seminar Research Bureau
Boston College

METROPOLITAN BOSTON RETAIL EMPLOYMENT, 1959 and 1980

Distribution by 100 Cities and Towns (Traffic Zones)

Sector I - Northeast

ZONE	MUNICIPALITY	Retail Employment 1959	1980
101	East Boston	2,532	2,700
102	Winthrop	384	500
103	Chelsea	1,671	1,800
104	Revere	1,440	1,700
105	Saugus	720	1,000
106	Lynn A	1,900	2,100
107	Lynn B, Nahant	3,007	3,300
108	Swampscott Marblehead	891	1,200
109	Salem	2,866	3,300
110	Peabody	2,913	4,100
111	Lynnfield	441	700
112	Danvers Topsfield Middleton	1,007	1,600
113	Beverly	1,277	1,600
114	Hamilton Wenham, Essex Ipwsich Manchester	714	1,100
115	Gloucester Rockport	1,538	1,900
Sector I - Total		23,301	28,600

Sector II - Northwest

201	Charlestown	1,242	1,200
202	Cambridge A	2,767	3,100
203	Cambridge B	4,237	4,700
204	Somerville A	1,092	1,200
205	Somerville B	1,564	1,700
206	Everett	1,394	1,600
207	Malden	3,112	3,700
208	Medford	2,241	2,600
209	Arlington	1,181	1,500
210	Belmont	877	1,100
211	Lexington	884	1,400
212	Winchester	564	800

Table # 2 (continued)

ZONE	MUNICIPALITY	Retail Employment 1959	1980
213	Stoneham	732	1,100
214	Melrose	635	800
215	Wakefield	868	1,200
216	Reading	535	800
217	Woburn	814	1,110
218	Lincoln, Acton Carlisle, Concord	711	1,000
219	Burlington Bedford	434	1,000
220	N. Reading Wilmington	431	600
Sector II - Total		26,315	32,300
Sector III - West			
301	Fens	1,290	1,400
302	Brighton	3,414	3,700
303	Brookline	3,073	3,800
304	Newton	2,330	2,800
305	Watertown	1,449	1,700
306	Waltham	2,893	3,800
307	Weston, Wayland	264	500
308	Wellesley	1,237	1,500
309	Needham, Dover	855	1,400
310	Natick	1,002	1,500
311	Sherborn Holliston Ashland	325	600
312	Framingham	3,187	4,600
313	Sudbury, Maynard	723	1,100
314			
Sector III - Total		22,042	28,200
Sector IV - Southwest			
402	Roxbury A	3,168	3,400
403	Roxbury B	2,772	3,000
404	Jamaica Plain	2,154	2,500
405	Roslindale	1,590	1,800
406	W. Roxbury	1,554	1,900
407	Hyde Park	1,878	2,200
408	Dedham	770	1,000
409	Westwood	177	300
410	Norwood	1,234	1,800
411	Walpole, Sharon	458	700
412	Medfield, Millis Norfolk, Medway	257	400

Table # 2 (continued)

ZONE	MUNICIPALITY	Retail Employment	
413	Foxboro Mansfield	632	900
Sector IV - Total		16,644	19,800
Sector V - Southeast			
501	South Boston	3,168	3,400
502	Dorchester A	2,982	3,400
503	Dorchester B	2,424	2,700
504	Dorchester C	1,566	1,800
505	Dorchester D	2,718	3,000
506	Milton	338	500
507	Quincy	4,944	5,900
508	Canton, Avon Stoughton	884	1,300
509	Randolph Holbrook	615	800
510	Braintree	689	1,000
511	Weymouth	1,032	1,400
512	Hingham, Hull Cohasset	1,051	1,700
513	Scituate Norwell Marshfield	566	1,000
514	Hanover Whitman Rockland Abington	1,305	1,800
515	Brockton	3,791	4,300
516	Easton W. Bridgewater	280	400
517	E. Bridgewater Bridgewater	552	800
518	Hanson, Pembrook Duxbury	286	500
Sector V - Total		29,191	35,800
000-5 Downtown		25,553	27,200
Grand Total		143,046	171,700

STUDIES OF URBAN TRANSPORTATION

Table # 3

Seminar Research Bureau
Boston College

Attractive Force for Personal Business Trips in Metropolitan Boston, 1959 and 1980

Distribution by 100 Cities and Towns (Traffic Zones)

Sector I - Northeast		Attractive Force	
ZONE	MUNICIPALITY	1959	1980
101	E. Boston	20,660	22,200
102	Winthrop	2,936	3,500
103	Chelsea	19,590	20,750
104	Revere	11,876	14,200
105	Saugus	5,985	8,150
106	Lynn A	26,500	28,800
107	Lynn B, Nahant	53,193	57,950
108	Swampscott Marblehead	7,190	9,800
109	Salem	30,222	34,900
110	Peabody	24,059	33,900
111	Lynnfield	3,052	4,850
112	Danvers Topsfield Middleton	13,166	21,150
113	Beverly	15,913	20,200
114	Hamilton Wenham, Essex Ipswich Manchester	6,421	9,550
115	Gloucester Rockport	15,798	19,700
Sector I - Total		256,561	309,600
Sector II - Northwest			
201	Charlestown	26,310	25,000
202	Cambridge A	43,835	48,400
203	Cambridge B	69,185	76,200
204	Somerville A	10,460	11,500
205	Somerville B	27,820	30,400
206	Everett	22,881	25,900
207	Malden	32,405	38,200
208	Medford	21,906	25,000
209	Arlington	10,389	13,550
210	Belmont	7,007	8,700
211	Lexington	7,385	11,700
212	Winchester	6,223	8,700
213	Stoneham	6,275	9,300

Table # 3 (continued)

ZONE	MUNICIPALITY	Attractive Force 1959	1980
214	Melrose	8,860	11,700
215	Wakefield	9,485	12,800
216	Reading	4,812	7,200
217	Woburn	10,574	14,500
218	Lincoln, Acton Carlisle, Concord	8,913	13,440
219	Burlington Bedford	7,464	17,450
220	N.Reading	3,717	5,500
Sector II- Total		345,906	414,900
Sector III - West			
301	Fens	33,250	36,100
302	Brighton	33,370	36,400
303	Brookline	27,810	34,300
304	Newton	36,682	43,000
305	Watertown	26,508	32,000
306	Waltham	47,443	62,300
307	Weston, Wayland	4,780	8,650
308	Wellesley	11,031	13,650
309	Needham, Dover	12,609	20,100
310	Natick	9,556	14,000
311	Sherborn Holliston Ashland	5,616	9,750
312	Framingham	34,402	50,100
313	Sudbury, Maynard	7,895	11,100
Sector III - Total		290,952	371,050
Sector IV - Southwest			
402	Roxbury A	28,940	30,600
403	Roxbury B	26,960	28,700
404	Jamaica Plain	19,270	21,650
405	Roslindale	11,350	12,800
406	W. Roxbury	10,870	13,200
407	Hyde Park	16,990	20,000
408	Dedham	9,433	11,800
409	Westwood	1,903	3,300
410	Norwood	15,372	22,000
411	Walpole, Sharon	7,892	11,000
412	Medfield, Millis Norfolk, Medway	3,234	4,890
413	Foxboro, Mansfield	8,920	12,850
Sector IV - Total		161,134	192,850

Table # 3 (continued)

Sector V - Southeast		Attractive Force	
ZONE	MUNICIPALITY	1959	1980
501	South Boston	42,040	44,700
502	Dorchester A	17,910	20,150
503	Dorchester B	15,120	16,800
504	Dorchester C	12,830	14,600
505	Dorchester D	23,590	25,900
506	Milton	3,309	4,700
507	Quincy	62,152	73,600
508	Canton, Avon Stoughton	11,840	17,700
509	Randolph Holbrook	5,688	7,660
510	Braintree	9,157	12,750
511	Weymouth	10,079	14,050
512	Hingham, Hull Cohasset	8,671	14,390
513	Scituate, Norwell Marshfield	4,630	8,350
514	Hanover, Whitman Rockland Abington	16,136	22,050
515	Brockton	45,003	50,300
516	Easton W. Bridgewater	2,892	4,080
517	E. Bridgewater Bridgewater Halifax	6,049	8,010
518	Hanson, Pembroke Duxbury	3,033	4,650
Sector V - Total		300,129	364,350
000-5 Downtown		370,734	396,000
Grand Total		1,725,447	2,050,250

STUDIES OF URBAN TRANSPORTATION

Table # 4

Seminar Research Bureau
Boston College

METROPOLITAN BOSTON POPULATION 1959 - 1980

Distribution by 100 Cities and Towns

Sector I - Northeast

ZONE	MUNICIPALITY	POPULATION 1959	POPULATION 1980
101	East Boston	49,000	45,000
102	Winthrop	20,000	23,600
103	Chelsea	38,200	33,400
104	Revere	41,000	47,200
105	Saugus	20,800	30,100
106	Lynn A	41,000	36,400
107	Lynn B, Nahant	67,100	63,000
108	Swampscott Marblehead	29,300	42,700
109	Salem	43,000	45,500
110	Peabody	30,800	47,800
111	Lynnfield	7,600	14,400
112	Danvers Topsfield Middleton	23,000	45,400
113	Beverly	34,900	45,100
114	Hamilton Wenham, Essex Ipswich Manchester	20,400	38,100
115	Gloucester Rockport	31,200	38,500
Sector I - Total		497,300	596,200

Sector II - Northwest

201	Charlestown	24,000	15,000
202	Cambridge A	47,100	44,400
203	Cambridge B	72,200	68,100
204	Somerville A	41,300	38,800
205	Somerville B	59,100	55,700
206	Everett	46,700	46,500
207	Malden	61,500	65,500
208	Medford	69,700	69,500
209	Arlington	46,500	61,200
210	Belmont	29,800	34,700
211	Lexington	24,500	45,800

Table # 4 (continued)

ZONE	MUNICIPALITY	POPULATION 1959	POPULATION 1980
212	Winchester	19,300	28,900
213	Stoneham	17,100	27,500
214	Melrose	29,500	39,900
215	Wakefield	24,000	33,100
216	Reading	18,400	30,800
217	Woburn	29,800	44,600
218	Lincoln		
	Concord		
	Acton		
	Carlisle	21,800	38,700
219	Burlington		
	Bedford	15,700	51,700
220	N. Reading		
	Wilmington	19,500	31,900
Sector II - Total		717,500	872,300
Sector III - West			
301	Fens	25,000	23,000
302	Brighton	66,000	62,000
303	Brookline	59,000	71,000
304	Newton	92,400	103,500
305	Watertown	40,000	45,900
306	Waltham	53,300	72,300
307	Weston		
	Wayland	16,700	34,900
308	Wellesley	25,300	30,900
309	Needham		
	Dover	26,900	51,500
310	Natick	27,000	44,700
311	Sherborn		
	Holliston		
	Ashland	12,900	27,400
312	Framingham	44,600	74,200
313	Sudbury		
	Maynard	13,800	23,000
Sector III - Total		502,850	664,300
Sector IV - Southwest			
402	Roxbury A	61,200	50,000
403	Roxbury B	53,600	45,000
404	Jamaica Plain	41,600	40,000
405	Roslindale	30,700	30,000
406	W. Roxbury	30,000	34,000
407	Hyde Park	36,300	36,000
408	Dedham	23,400	28,200
409	Westwood	9,200	20,400
410	Norwood	23,800	37,000
411	Walpole, Sharon	21,800	35,400

Table # 4 (continued)

ZONE	MUNICIPALITY	POPULATION 1959	POPULATION 1980
412	Medfield		
	Millis		
	Norfolk		
	Medway	16,800	29,900
413	Foxboro		
	Mansfield	17,400	27,600
Sector IV - Total		365,800	413,500
Sector V - Southeast			
501	South Boston	61,300	52,000
502	Dorchester A	57,600	55,000
503	Dorchester B	46,800	45,000
504	Dorchester C	30,200	30,000
505	Dorchester D	52,500	48,000
506	Milton	26,000	39,300
507	Quincy	89,000	97,500
508	Canton, Avon	30,400	50,600
	Stoughton		
509	Randolph, Holbrook	28,400	40,900
510	Braintree	30,200	45,100
511	Weymouth	44,300	65,000
512	Hingham		
	Cohasset, Hull	22,400	43,600
513	Scituate		
	Norwell		
	Marshfield	16,800	38,200
514	Hanover, Rockland		
	Whitman, Abington	36,000	54,500
515	Brockton	68,000	65,200
516	Easton		
	W. Bridgewater	12,700	18,800
517	E. Bridgewater	5,200	
	Bridgewater		
	Halifax	16,800	23,500
518	Hanson		
	Pembrook		
	Duxbury	13,000	23,100
Sector V - Total		682,300	835,300
000 - 5 Downtown		100,000	90,000
Grand Total		2,865,800	3,471,600

STUDIES OF URBAN TRANSPORTATION

Table # 5

Seminar Research Bureau
Boston College

Attractive Force for Combined Non-Work Trips in Metropolitan Boston, 1959 and 1980

Distribution by 100 Cities and Towns (Traffic Zones)

Sector I - Northeast

ZONE	MUNICIPALITY	1959	1980
101	E. Boston	21,064	29,350
102	Winthrop	6,046	10,023
103	Chelsea	16,428	22,309
104	Revere	15,009	24,786
105	Saugus	7,552	15,051
106	Lynn A	18,748	20,272
107	Lynn B, Nahant	32,296	46,691
108	Swampscott Marblehead	10,247	20,581
109	Salem	22,185	34,607
110	Peabody	18,128	37,616
111	Lynnfield	3,287	8,232
112	Danvers Topsfield Middleton	10,027	25,637
113	Beverly	13,825	24,959
114	Hamilton Wenham, Essex Ipswich Manchester	7,466	19,284
115	Gloucester Rockport	13,696	24,092
Sector I - Total		216,004	363,490

Sector II - Northwest

201	Charlestown	13,267	15,498
202	Cambridge A	25,479	37,165
203	Cambridge B	39,441	57,583
204	Somerville A	14,012	19,576
205	Somerville B	22,459	31,602
206	Everett	17,988	27,190
207	Malden	27,213	43,294
208	Medford	24,964	37,769
209	Arlington	14,997	27,773
210	Belmont	10,336	17,427
211	Lexington	8,980	22,447
212	Winchester	6,961	14,291
213	Stoneham	6,706	14,677

Table # 5 (continued)

ZONE	MUNICIPALITY	Attractive Force 1959	Attractive Force 1980
214	Melrose	9,982	18,845
215	Wakefield	9,258	18,100
216	Reading	6,298	14,260
217	Woburn	10,422	21,503
218	Lincoln, Acton Carlisle, Concord	8,155	21,438
219	Burlington Bedford	5,845	24,239
220	N. Reading Wilmington	5,988	13,302
Sector II - Total		288,751	497,979
Sector III - West			
301	Fens	15,288	21,969
302	Brighton	29,540	42,092
303	Brookline	26,473	45,493
304	Newton	33,765	53,785
305	Watertown	17,450	29,979
306	Waltham	27,466	51,784
307	Weston, Wayland	5,296	15,047
308	Wellesley	10,738	18,647
309	Needham, Dover	10,431	26,352
310	Natick	10,037	22,516
311	Sherborn Holliston Ashland	4,637	13,046
312	Framingham	23,688	51,475
313	Sudbury, Maynard	6,267	13,869
Sector III - Total		221,076	406,054
Sector IV - Southwest			
402	Roxbury A	26,640	35,245
403	Roxbury B	23,757	32,018
404	Jamaica Plain	18,177	26,592
405	Roslindale	12,880	18,918
406	W. Roxbury	12,558	20,796
407	Hyde Park	15,714	24,161
408	Dedham	8,874	15,318
409	Westwood	2,839	8,368
410	Norwood	11,027	23,525
411	Walpole, Sharon	7,369	16,271
412	Medfield, Millis Norfolk, Medway	4,633	11,588
413	Foxboro, Mansfield	7,130	15,404
Sector IV - Total		151,598	248,204

Table # 5 (continued)

Sector V - Southeast		Attractive Force	
ZONE	MUNICIPALITY	1959	1980
501	South Boston	29,111	39,690
502	Dorchester A	23,598	34,213
503	Dorchester B	19,271	27,926
504	Dorchester C	12,922	19,392
505	Dorchester D	22,363	31,644
506	Milton	7,607	16,220
507	Quincy	43,479	70,169
508	Canton, Avon Stoughton	11,047	24,896
509	Randolph Holbrook	8,804	17,782
510	Braintree	10,159	20,990
511	Weymouth	14,115	28,679
512	Hingham, Hull Cohasset	9,082	23,574
513	Scituate, Norwell Marshfield	5,923	17,718
514	Hanover, Whitman Rockland, Abington	14,136	29,024
515	Brockton	32,920	48,757
516	Easton W. Bridgewater	4,078	8,530
517	E. Bridgewater Bridgewater Halifax	5,718	12,133
518	Hanson, Pembroke Duxbury	4,197	10,293
Sector V - Total		278,530	481,630
000-5	Downtown	223,623	330,943
Grand Total		1,379,582	2,328,300

TRAVEL TIME

The travel time or distance factor is the most important single factor in the gravity model equation because of the strength given it by the exponent.

In most recent origin and destination studies this factor is measured by "in-the-field" tests of the time taken to travel from one point to another in the metropolitan area. In most cases every major street and highway is traveled and recorded three or four times to assure good average speeds.

In other studies the straight line distance measured between zones is taken as an adequate measure of the friction factor. This process is probably adequate for a model of this type if the city of study has few expressways or major facilities that offer substantially greater speeds. Metropolitan Boston, however, contains many types of facilities that offer varying degrees of speed, so that any attempt to use only a straight line measured distance would cause significant errors and impair the usefulness of the model.

To diminish the effects of any such error, this study has utilized a combination of both the field check of travel speeds and the straight line distance measurements.

In the first instance all major facilities were measured for all off-peak hour travel speeds. Each was measured twice and the average of the two measurements was used. Where construction, or unusual incidents such as a fire that would cause travel delay were encountered, measurements were not taken.

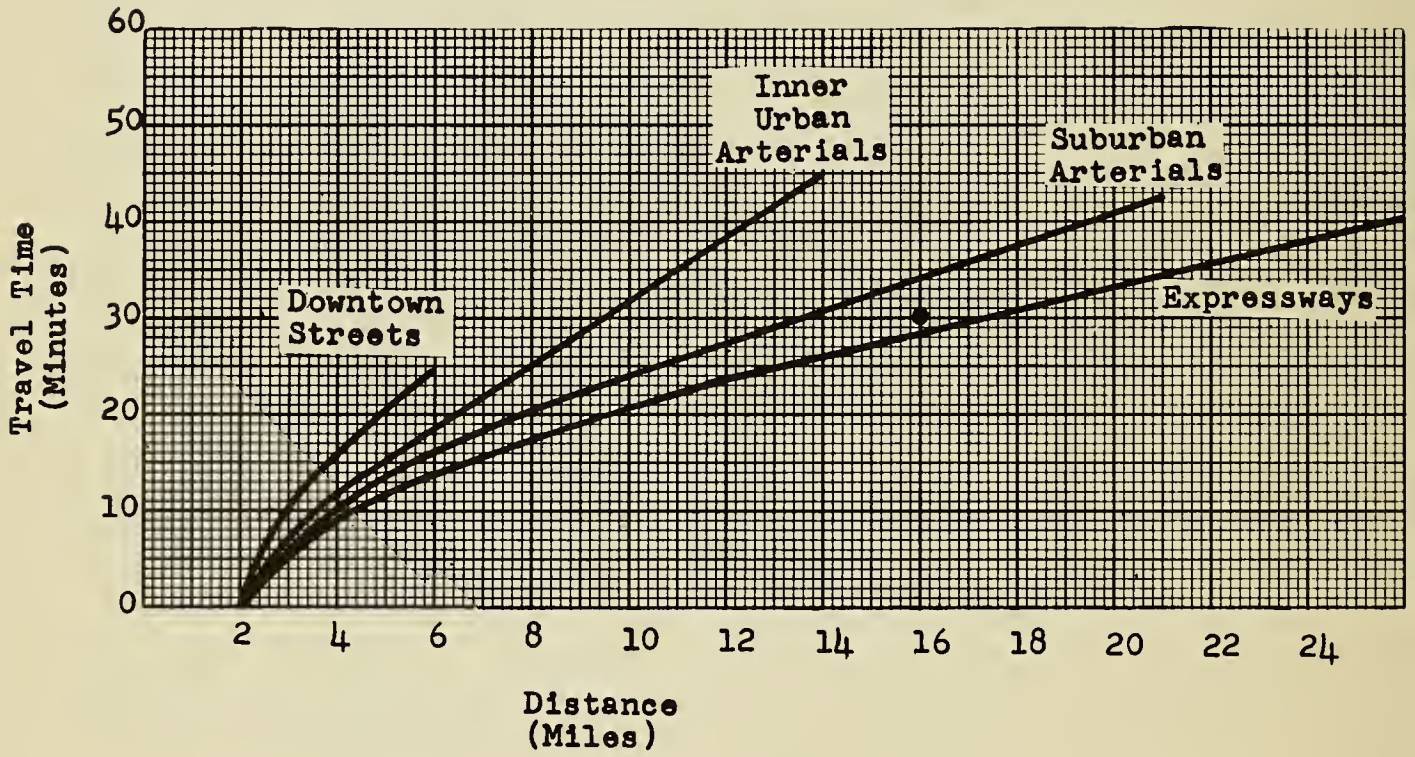
The data collected from these on-the-road tests was used in constructing Chart A shown on Page 42 . The chart shows

STUDIES OF URBAN TRANSPORTATION

Chart # A

Seminar Research Bureau
Boston College

Automobile Trip Travel Time
(By Type of Highway and Trip Length)



the time required to travel various distances along four basic types of facility: the Downtown street, which is usually the most congested type of street and, therefore, the type upon which the lowest speeds can be attained; the major street in the inner part of the metropolitan area; the major arterial or highway; and the limited access expressway upon which the greatest speeds can be attained (up to 60 miles per hour.)

The chart has been drawn to reflect the fact that shorter trips can never reach the average maximum travel speed of the best facility used because of the time that must be spent in getting away from the place of parking, onto the major street and then off it again. Therefore, the shorter trip will inherently have a much lower average speed than the longer trip. Of course, the fact that the major facility is rarely utilized in shorter trips contributes to this result. Even the longest possible trip within the metropolitan area cannot attain an average speed equal to the maximum travel speeds of the highways partially used for the trip because of the time spent in getting the trip started and ended.

The curves in the graph were derived in the following way:

(a) Travel distances (on the horizontal axis) were determined from both the road speed tests and measurements taken on a map of the highway system. (The distance between zones was measured from the center of one zone to the center of another.)

(b) Travel times (on the vertical axis) were determined by traveling the actual routes involved twice, and taking the mean of the two times.

(c) Corresponding times and distances were plotted on the graph for each type of facility, and a curve was fitted to each set of coordinates.

Thus the use of the graph involves simply determining the distance traveled on a trip, relating the distance to the appropriate curve of the graph, and reading off the corresponding travel time.

One important refinement is needed, however, in using the graph. In virtually every trip made, a combination of these four facilities is used, rather than just one. For example, a trip between two zones connected directly by Route 128 could not be assumed to have been undertaken entirely on an expressway. Such a trip would consume a good deal of time on local suburban streets before and after driving on Route 128. Therefore, visual inspection and a knowledge of the facilities available would be required to identify the point on the graph best suited to the proportionate mileage on each of these facilities. In other words, the point determining the travel time would not lie on a curve, but between two curves.

So, for example, if our hypothetical trip covered a total distance of sixteen miles, and we assume that one-fourth of the trip took place on local suburban streets, and three-fourths on Route 128, the appropriate point determining the travel time would lie at one-fourth of the vertical distance between the expressway curve and the curve for suburban highways (measured from the expressway curve). Thus, as shown on the graph, the time consumed would be about 30 minutes.

In all cases the travel time selected was the shortest time but not necessarily the shortest mileage. In many instances, the

availability of higher average speeds on Route 128 and on the Northeast and Southeast Expressways provides less travel time than more direct routes over local streets and highways.

Terminal Time

The most interesting feature of this travel time analysis is the measurement of "terminal time." This is a factor not heretofore used in determining travel time. The computations described above account for only that time spent while in a vehicle. But a "trip" actually includes the time it takes to move from the door of a building to the door of another building.16/

A factor for "terminal time" was added to each of the trip lengths (minutes) computed above. The bases for determining the amount of terminal time were the results of the home-to-home survey (when all those interviewed were asked to give the time spent in door-to-vehicular movement), and some judgment. The survey data indicated that terminal time varied according to the location of the origin and destination and according to the type of trip. For example, trips starting or ending in the suburbs involved much less terminal time (one or two minutes) than did trips starting or ending in the Downtown area (as much as 15 minutes). The pattern shows that the closer one gets to Downtown, the longer it takes to park his car and walk to the building of his final destination - and the longer the "terminal time."

The data also showed that terminal times for shopping trips averaged higher than that for work trips. This, too, is not unexpected because shopping trips most often take place during the

16/ To be even more accurate a trip could be identified as including such movements as putting on one's coat, using an elevator, and a number of other incidents that act to lengthen or impede the trip.

middle of the day when parking space is more difficult to find, and often necessitate longer walking distances.

Table 6 shows the terminal times that were added to the travel times of all trips depending on the trip origin, destination and purpose.

Using the figures described above, the Gravity Model computations were carried out for each of the following conditions:

1. 1959 Work Trips
2. 1959 Non-Work Trips
3. 1980 Work Trips (Alternative 1 - with a greater number of jobs downtown)
4. 1980 Non-Work Trips (Alternative 1 - with a greater number of jobs downtown)
5. 1980 Work Trips (Alternative 2 - with a greater number of jobs along Route 128)
6. 1980 Non-Work Trips (Alternative 2 - with a greater number of jobs along Route 128)

In computations #1, 2 and 5 an exponent of 3.5 was used.

In computations #2, 4 and 6 an exponent of 5.0 was used.

Table # 6

TERMINAL TIME OF TRIPS IN METROPOLITAN BOSTON (Minutes)

PURPOSE AT TRIP END	TRAFFIC ZONES			ALL OTHER TRAFFIC ZONES
	000	001, 002, 003 004, 005, 301	101,103,201,203,205, 206,402,403,501,505	
Home-Based Trip End		3	2	1
work business related to work recreation social education,civic or religious	6	4	3	2
shopping for shopping goods shopping for convenience goods personal business	10	5	4	3

FINDINGS

The findings of a study of this nature are numerous. Many become lost in the scope of the study. Because the primary objective of the study is to develop and utilize a proper transportation analysis procedure, emphasis is placed here on the description of the results of this methodology. However, the reader is reminded that all of the previously described data concerning population, employment, travel times, and terminal times are in fact, the results of considerable research.

The findings related below are restricted to the procedures and direct results of the gravity model. As a general conclusion, the Seminar Research Bureau believes that with a few qualifications the process and the computations proved successful and useable for urban transportation analysis.

Exponential Investigation

Early in this study, the Bureau decided to accept the general form of the Gravity Model equation as a reasonable and useful expression of average travel habit characteristics. But, for reasons stated above, we believed that the exponential value deserved further investigation because of the strong probability that it would vary for a number of conditions.

These investigations of the best exponent for the Boston region (because of the nature of the input data used) were time consuming and relatively costly. However, events have demonstrated that they were necessary and justified. Only through this investigation was it possible to arrive at satisfactory and acceptable values to use in distributing the many trips made throughout Metropolitan Boston.

In the case of the exponent of 3.5 for work trips there is the greatest confidence that this value is best and that the results of its use are satisfactory. The exponent 5.0 for non-work trips is also the best single value for these kinds of trips, and as such, satisfactory and useable. But in the case of non-work trips, the Bureau recognized that the many and varied types of non-work trips carry with them a wider range of travel characteristics that are more difficult to average out with one value. A greater amount of data about each of the non-work trip classifications would have allowed a more accurate and separate investigation of the best exponent for each type of trip. But the costs of obtaining this data for these types of trips--which comprise but a small proportion of the total daily trips - was prohibitive.

In addition there is reason to believe that such analysis would determine lower exponents for some types of trips and higher exponents for others (depending to a great extent on the nature of the input data) which, if averaged out on a pro-rated bases, would be near the value selected here of 5.0. Therefore, a detailed examination of this kind becomes essentially academic when one faces the necessity of combining all trips together for highway assignment and transportation facility evaluation. It is strongly suspected that the differences in trip distribution that would result from this process would not justify the added costs involved unless or until better means are devised of estimating the magnitude of attractive forces for each of the non-work categories.

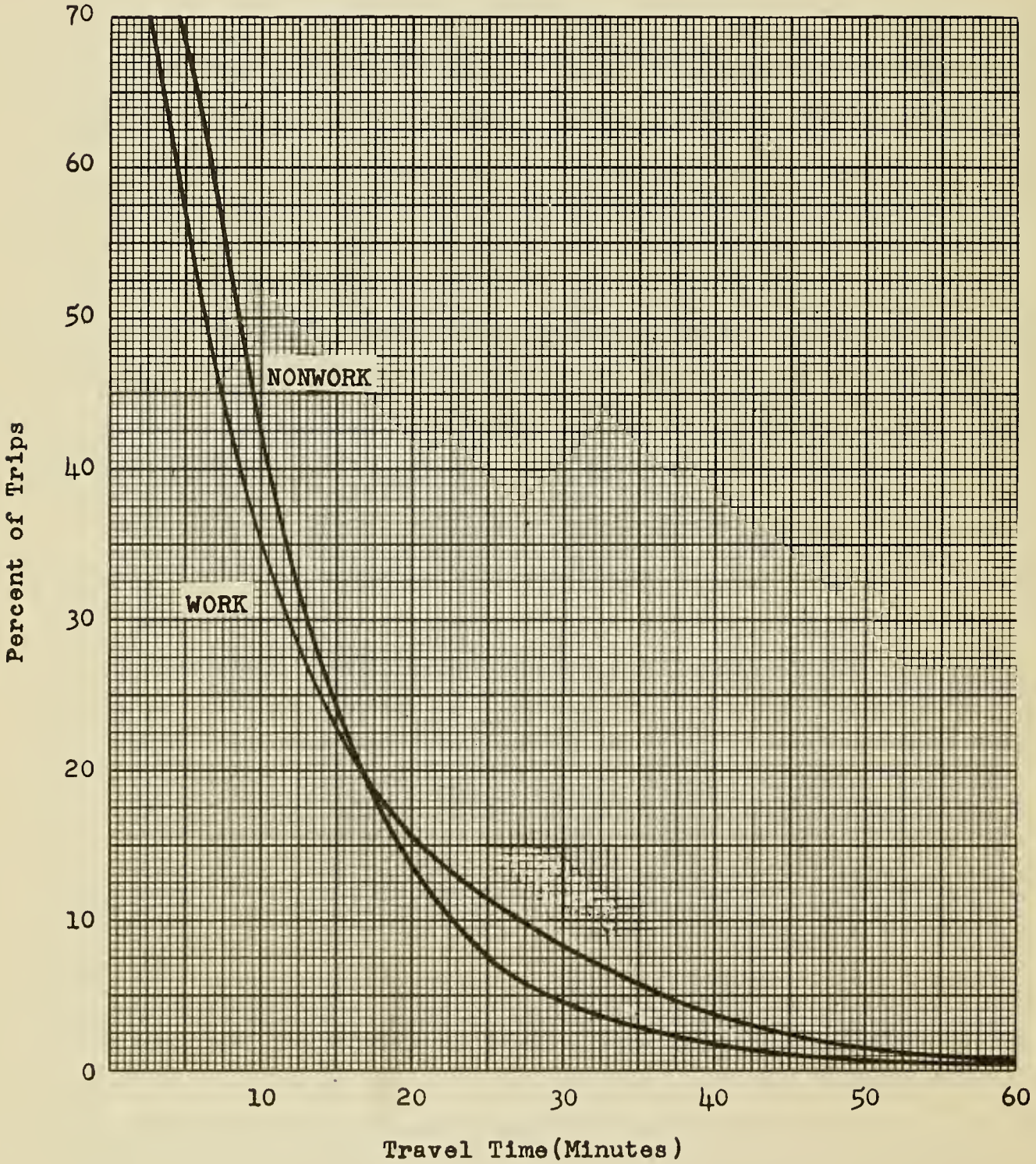
The nature of the pattern of trip distribution caused by the exponents of 3.5 for work trips and 5.0 for non-work trips

STUDIES OF URBAN TRANSPORTATION

Chart # B

Seminar Research Bureau
Boston College

Model Distribution of Work and Non-Work Trips
in the Boston Region



is shown in Chart B. The graph shows the percent of total trips that are made for each of the time distances indicated. For example, 30% of the daily work trips take 12.5 minutes; 50% take 6.5 minutes. The curve for non-work trips shows that a smaller percentage make shorter trips and a larger percentage make longer trips; e.g., 30% of the daily non-work trips take 13 minutes. 50% take 8.5 minutes. Chart C shows the accumulated distribution of work and non-work trips.

These curves reflect the average condition throughout the entire Metropolitan Area, but not the habits of the residents of each city or town. The actual pattern of trips from each city or town is influenced toward the average distribution shown in the curve and also by the nearness and size of attractive forces. The net result is that the inhabitants of an inner zone (such as Roxbury) make shorter trips than do residents of an outlying suburb because of the abundance of jobs and other destinations in close proximity to the inner zone.

Two examples of the geographic distribution of trips caused by the model and the nature of its components are shown in Maps II and III.

Map II shows the difference in the number of trips from the Brighton-Brookline-Fens Area to Cambridge and Newton. Both of these communities are approximately equi-distant from the Area, but Cambridge has more jobs and, therefore, greater attraction.

Map III shows the distribution of 1959 home-based trips originating in the Canton-Stoughton traffic area. If intra-area trips are excluded, it is seen that longer trips are dominant from this area, and only 25% of these trips are destined for Downtown. This pattern is totally different from that shown in Map II, and

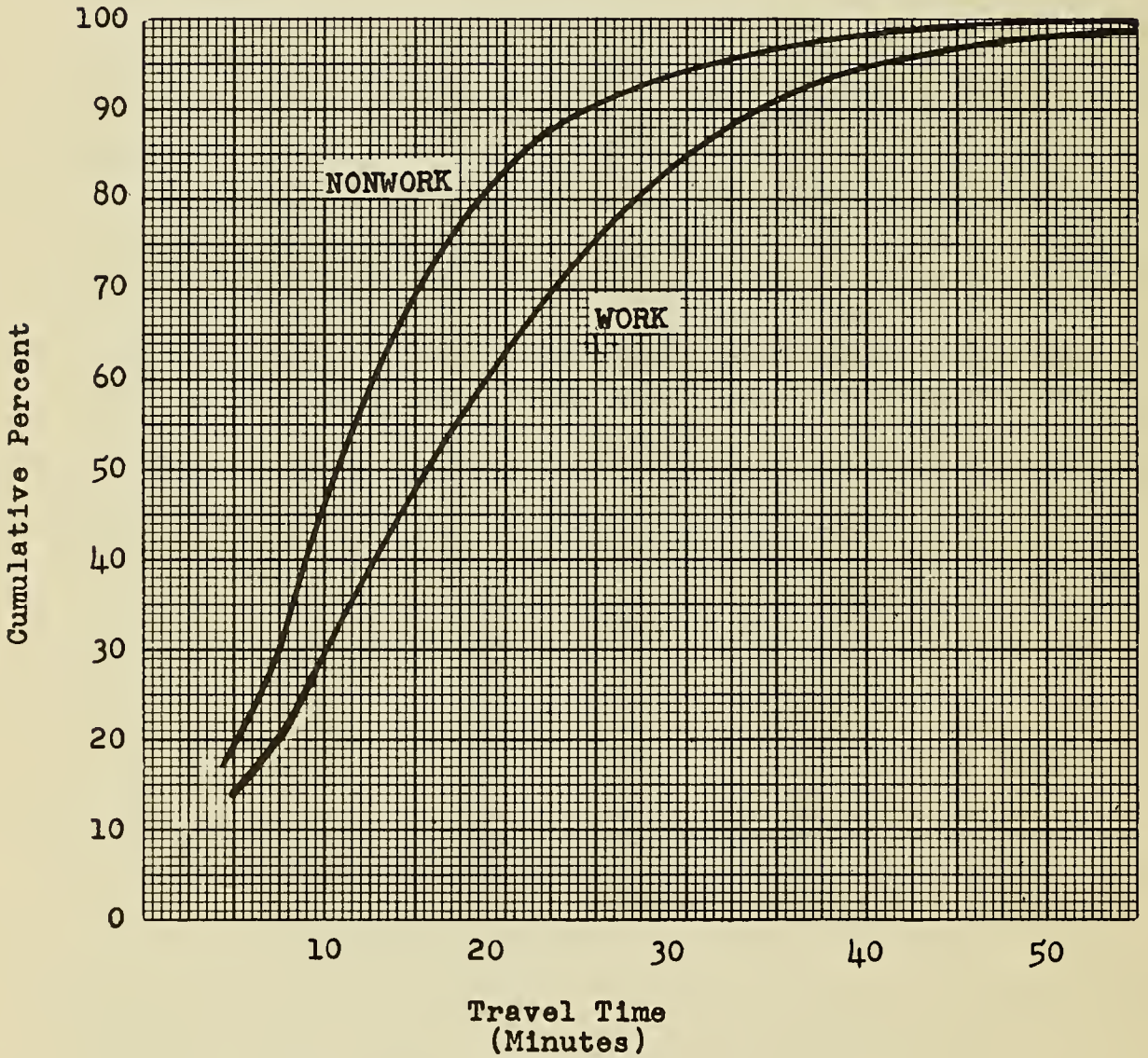
STUDIES OF URBAN TRANSPORTATION

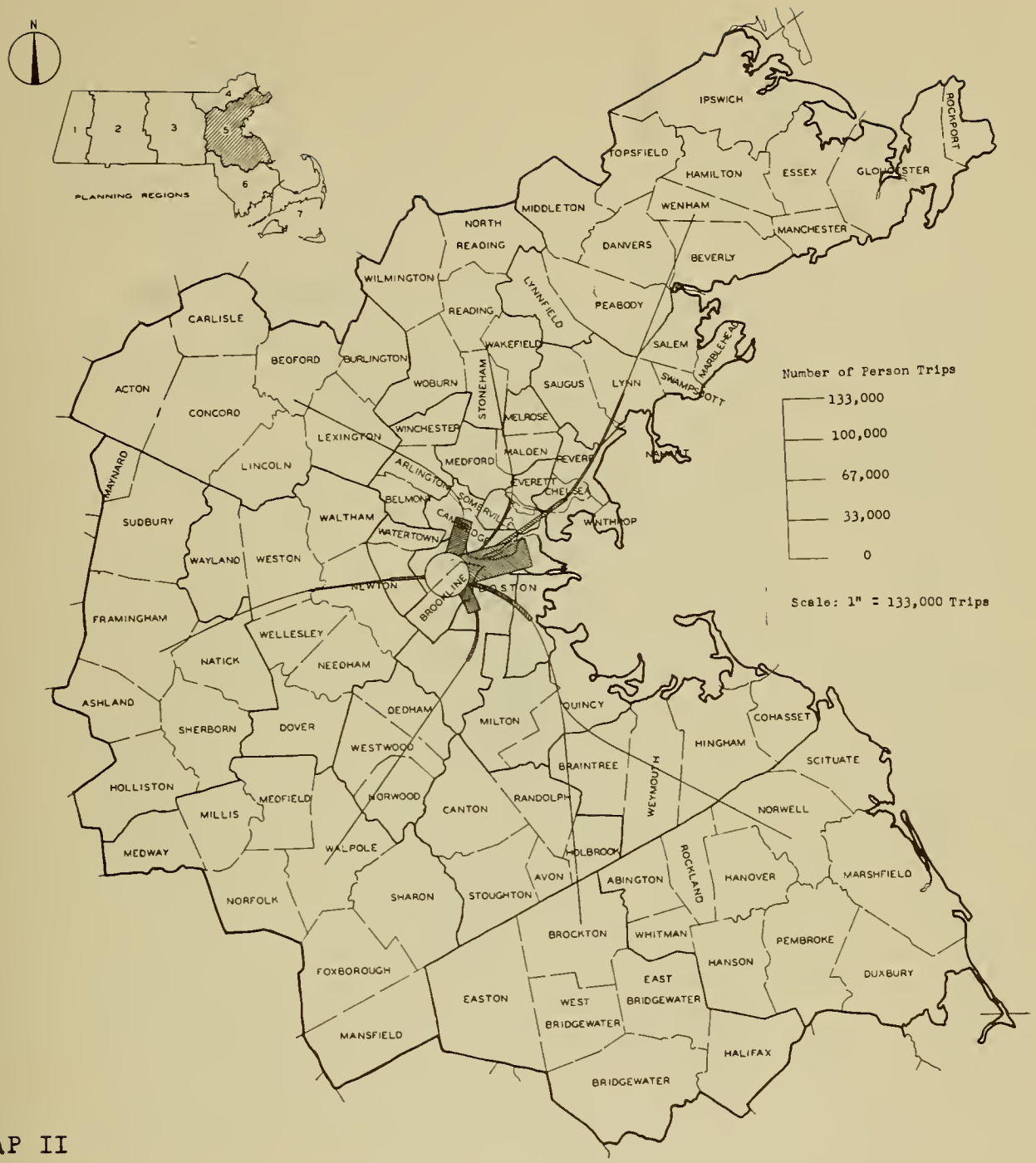
Chart # C

Seminar Research Bureau
Boston College

Accumulated Model Distribution of Work and Non-Work Trips
in the Boston Region

(By Minutes of Travel)





MAP II

DISTRIBUTION OF TOTAL DAILY 1959 PERSON TRIPS ORIGINATING IN BRIGHTON, BROOKLINE, AND THE FENS (AREA K) *

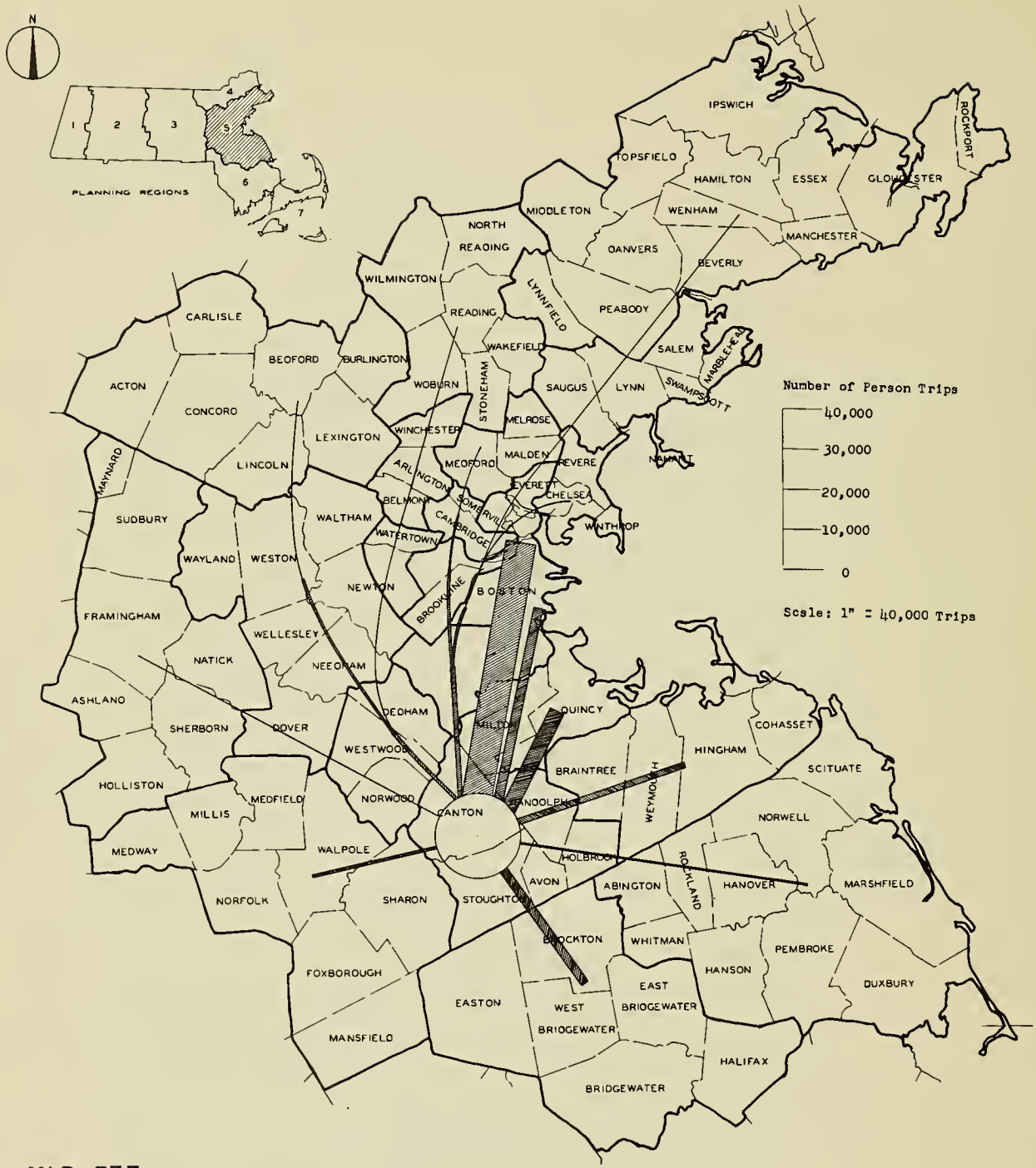
* Excluding intra-area trips originating in and destined for Brighton, Brookline, and the Fens

---

STUDIES OF URBAN TRANSPORTATION

SEMINAR RESEARCH BUREAU BOSTON COLLEGE

February 1961



MAP III

DISTRIBUTION OF TOTAL DAILY 1959 PERSON TRIPS ORIGINATING IN CANTON, STOUGHTON TRAFFIC AREA (AREA U) *

* Excluding intra-area trips originating in and destined for Canton, Stoughton area

---

STUDIES OF URBAN TRANSPORTATION

SEMINAR RESEARCH BUREAU BOSTON COLLEGE

February 1961

is caused by a number of factors: the relative scarcity of near-by attractors; the fact that this area is in an outer zone; and, the great difference in the types of transport facilities available to residents of the Canton - Stoughton Area and the Brighton - Brookline - Fens Area.

Trip Origin and Destination Tables

The results of the final origin and destination computations are shown in Tables 7 through 13. For simplicity of presentation and use, the data has been regrouped into a smaller number of originating and destination traffic areas. The actual calculations of the model determined the trip patterns from each of the 84 traffic zones to all of the other 83 traffic zones as well as to the originating zone (intra-zonal trips.) As a result there are some 7056 possible travel movements. The 84 traffic zones and the data have been consolidated into 25 traffic areas, as shown on Map IV. This has reduced the total number of travel movements to 625 possible origin and destination patterns.

The figures shown in the following tables are the number of estimated work and non-work trips in 1959 and 1980 (as indicated) from each originating area to each traffic area of destination. They show the number of daily one-directional home-based trips by persons residing within the Boston Region. These figurea represent the basic pattern of trips throughout the Region; and, as such, constitute the foundation of all travel data used in these studies for evaluation of the future transportation requirements of the region. They are easily expanded to include any other type of trip that is undertaken in the region. These figures represent approximately two-thirds to three-quarters of the number of daily person-trips in the region in vehicles. The figures

in these tables do not include the return trip (from the point of original destination back to the home). They do not include non-home based trips. They do not include truck driver trips. Nor do they include external trips made to and from areas beyond the Boston Region of 100 cities and towns.

Table # 7 shows the estimated 1959 Total Trips origins and destinations

Table # 8 shows the estimated 1980 Total Trip origins and destinations for Alternative #1 where a greater number of jobs were assigned to Downtown.

Table # 9 shows the estimated 1959 Work Trip origins and destinations.

Table # 10 shows the estimated 1959 Non-Work Trip origins and destinations.

Table # 11 shows the estimated 1980 Work Trip origins and destinations for Alternative #1 where a greater number of jobs have been assigned to Downtown.

Table # 12 shows the estimated 1980 Non-Work Trip origins and destinations for Alternative #1 where a greater number of jobs have been assigned to Downtown

Table # 13 shows the estimated 1980 Work Trip origins and destinations for Alternative #2 where a greater number of jobs have been assigned to Route 128.[17]

The Seminar Research Bureau encourages the proper use of this data for analyzing and planning transportation facilities in Metropolitan Boston. In reproducing the detailed origin and

17/The 1980 Non-Work Origins and Destinations for Alternative #2 contained errors of computation which restrict their usefulness, and they are not reproduced in order to avoid their misuse.

MAP IV

THE BOSTON REGION - TRAFFIC ZONES AND TRAFFIC AREAS

STUDIES OF URBAN TRANSPORTATION

SEMINAR RESEARCH BUREAU BOSTON COLLEGE

February 1961

Table # 7

Seminar Research Bureau
Boston College

ORIGINS AND DESTINATIONS IN THE BOSTON REGION *
1959 Total Daily Person Trips
(One Direction Distribution By Travel Area)

DESTINATION

ORIGIN	A	B	C	D	E
A	66,729	812	335	94	1,978
B	31,364	48,946	5,069	909	10,182
C	13,395	5,039	124,705	9,018	3,501
D	12,030	2,608	17,110	88,143	1,705
E	29,745	6,410	1,596	321	32,804
F	22,562	6,082	4,517	875	16,713
G	13,331	1,837	4,980	3,196	3,510
H	28,457	1,941	818	256	12,402
I	13,885	931	1,010	384	3,393
J	8,564	751	910	469	1,332
K	25,937	861	497	157	3,435
L	7,828	587	288	94	1,418
M	14,416	1,041	620	249	2,349
N	6,942	348	264	155	999
O	31,266	540	401	143	2,007
P	9,422	352	384	137	1,233
Q	4,597	253	156	63	624
R	6,090	216	128	67	781
S	46,074	1,168	924	270	3,625
T	28,809	719	630	208	1,802
U	7,648	363	315	108	829
V	7,316	355	325	123	670
W	17,071	603	450	155	1,251
X	12,742	583	363	134	920

Table # 7 (continued) DESTINATION

ORIGIN	F	G	H	I	J
A	281	75	2,289	93	49
B	2,959	346	3,224	177	133
C	2,839	966	1,483	248	202
D	1,267	1,865	1,102	283	278
E	6,286	399	10,560	394	46
F	57,323	2,703	9,635	2,207	527
G	6,851	42,550	4,236	3,051	1,855
H	3,168	498	61,712	2,017	296
I	5,463	2,528	14,234	24,468	037
J	1,620	2,264	3,091	2,018	28,557
K	732	223	15,008	576	181
L	551	204	6,961	3,081	389
M	1,396	508	7,446	2,400	1,173
N	607	225	1,617	380	608
O	424	127	4,704	226	91
P	406	142	2,472	231	196
Q	268	81	1,084	181	132
R	424	127	1,148	157	111
S	774	206	3,371	142	109
T	458	140	2,370	112	125
U	246	79	838	71	95
V	229	79	698	59	74
W	366	111	1,254	80	96
X	315	95	939	76	75

Table # 7 (continued) DESTINATION

ORIGIN	K	L	M	N	O
A	2,071	175	225	64	2,050
B	1,387	365	526	105	631
C	691	182	332	79	381
D	628	162	417	166	434
E	2,285	462	611	158	1,192
F	1,937	712	1,411	329	990
G	1,371	634	1,249	320	721
H	8,404	2,240	1,963	265	2,540
I	3,068	6,645	4,404	348	1,366
J	1,125	1,362	3,659	1,022	524
K	55,466	3,417	2,813	269	10,523
L	6,895	33,936	27,318	406	1,783
M	7,545	27,326	89,911	2,572	2,986
N	1,206	917	4,499	66,321	716
O	12,510	827	1,112	178	48,318
P	4,660	1,478	2,574	476	4,457
Q	1,616	722	2,424	473	1,312
R	989	441	1,803	1,135	709
S	4,469	618	930	165	10,453
T	3,808	669	1,265	280	7,278
U	903	334	908	280	1,028
V	998	253	722	258	1,086
W	1,444	307	759	203	1,843
X	1,116	205	511	143	1,439

Table # 7 (continued) DESTINATION

ORIGIN	P	Q	R	S	T
A	73	37	29	2,494	500
B	77	65	36	1,799	367
C	64	41	26	1,217	264
D	75	54	35	958	280
E	127	85	62	2,327	368
F	177	141	109	2,289	427
G	150	107	91	1,546	339
H	258	142	78	2,441	454
I	262	163	72	991	231
J	270	164	62	661	286
K	1,025	296	100	3,263	1,052
L	898	332	101	1,248	520
M	2,408	1,732	466	2,382	1,412
N	559	537	419	588	441
O	1,014	235	83	9,962	2,317
P	32,555	2,247	345	3,932	4,550
Q	4,678	25,805	894	1,415	1,729
R	923	2,398	26,797	1,336	1,099
S	1,315	313	152	52,249	11,965
T	3,806	808	274	22,896	67,365
U	1,236	1,277	806	2,426	3,444
V	661	661	893	2,141	2,660
W	979	496	265	6,093	12,249
X	617	403	243	3,365	3,366

Table # 7 (continued) DESTINATION

ORIGIN	U	V	W	X
A	23	28	58	17
B	41	55	71	32
C	34	47	59	25
D	34	51	60	29
E	42	48	68	27
F	55	67	89	39
G	46	59	70	34
H	48	53	75	31
I	33	32	44	18
J	50	41	55	21
K	74	98	121	46
L	73	56	64	22
M	270	215	241	75
N	127	112	91	33
O	90	114	161	55
P	411	276	406	113
Q	540	264	253	85
R	845	528	255	98
S	213	238	566	120
T	532	553	2,087	246
U	22,392	2,181	1,573	445
V	2,059	63,846	1,315	1,946
W	965	1,116	36,355	889
X	923	3,938	3,275	32,884

* See Report #3 relative to adjustment for Downtown Boston

STUDIES OF URBAN TRANSPORTATION

Table # 8

Seminar Research Bureau
Boston College

ORIGINS AND DESTINATIONS IN THE BOSTON REGION *
1980 Total Daily Person Trips
(One Direction Distribution By Travel Area)

DESTINATION

ORIGIN	A	B	C	D	E
A	66,815	878	347	102	2,176
B	31,168	59,135	5,956	1,052	10,369
C	16,148	8,161	155,426	11,698	5,636
D	23,319	6,385	31,280	171,314	3,954
E	25,643	7,388	2,178	433	32,974
F	30,360	7,695	5,695	1,171	18,725
G	28,521	3,369	7,191	5,143	6,740
H	34,321	2,538	789	268	11,113
I	20,558	1,835	1,286	500	5,952
J	25,529	2,499	1,832	988	5,545
K	19,671	900	701	182	3,620
L	14,887	758	427	134	1,686
M	37,428	2,129	1,140	369	3,973
N	17,060	795	622	265	2,139
O	22,077	834	587	150	2,040
P	13,542	640	469	137	1,148
Q	11,305	639	330	104	891
R	11,567	841	434	148	1,436
S	40,100	1,081	876	262	3,797
T	30,653	855	964	321	2,240
U	13,208	677	594	215	1,272
V	10,212	419	462	180	759
W	34,257	1,095	1,009	357	2,070
X	31,633	1,274	1,092	419	1,945

Table # 8 (continued) DESTINATION

ORIGIN	F	G	H	I	J
A	432	120	4,710	174	91
B	3,432	417	5,197	298	231
C	4,701	1,376	2,397	388	283
D	3,303	4,597	3,072	716	613
E	7,652	483	10,555	567	282
F	76,284	3,732	11,038	2,914	801
G	11,932	80,564	7,582	5,673	3,273
H	2,975	477	62,021	2,112	384
I	8,987	4,155	21,313	41,677	1,779
J	5,256	5,809	8,795	5,539	78,845
K	1,053	314	17,553	692	249
L	951	269	8,411	4,212	476
M	2,679	831	11,419	4,150	1,930
N	1,236	420	3,763	880	1,216
O	555	175	4,514	255	189
P	500	173	2,563	235	196
Q	487	154	1,975	282	201
R	867	258	2,432	336	220
S	905	249	3,695	216	181
T	714	237	3,204	210	209
U	551	188	1,832	151	160
V	331	113	1,204	95	103
W	840	272	2,405	239	201
X	862	287	2,429	248	241

Table # 8 (continued)

ORIGIN	DESTINATION K	L	M	N	O
A	2,079	445	579	97	2,488
B	1,494	503	804	132	1,254
C	1,157	328	556	123	912
D	1,573	468	930	279	1,109
E	2,252	521	732	163	1,233
F	2,856	1,184	1,989	340	1,744
G	3,181	1,278	2,192	434	1,959
H	8,379	2,263	1,917	249	2,386
I	4,437	9,704	6,368-	425	2,247.
J	3,445	3,057	8,232	1,807	2,918
K	73,569	4,094	3,473	347	13,249
L	8,951	45,719	36,137	405	2,134
M	12,600	38,402	155,156	3,936	5,672
N	3,327	1,846	9,070	136,417	1,936
O	12,161	831	1,295	183	46,824
P	4,718	1,417	2,439	399	6,196
Q	2,798	1,123	3,784	652	3,369
R	2,688	869	3,717	2,179	2,170
S	4,696	637	1,245	188	10,496
T	4,600	819	1,856	326	8,120
U	1,922	604	1,610	478	2,478
V	1,375	348	1,007	356	1,680
W	3,368	598	1,559	368	3,826
X	3,026	553	1,489	365	3,636

Table # 8 (continued) DESTINATION

ORIGIN	P	Q	R	S	T
A	298	90	36	3,116	563
B	243	130	79	1,795	374
C	181	90	57	1,634	512
D	299	128	84	2,066	739
E	183	91	58	2,404	393
F	372	186	123	3,120	600
G	473	234	139	2,834	746
H	345	158	72	2,146	445
I	511	224	93	1,923	470
J	789	358	121	2,561	834
K	1,619	369	147	4,722	1,367
L	1,365	400	102	1,396	622
M	5,340	3,597	711	4,926	2,734
N	1,561	1,147	789	1,733	953
O	1,781	372	103	9,520	2,359
P	37,224	2,005	338	4,036	4,218
Q	8,239	46,508	1,286	3,582	4,626
R	2,591	4,907	53,967	4,177	4,161
S	1,650	597	262	52,656	12,813
T	6,353	1,812	560	28,185	91,706
U	2,728	2,465	1,353	4,169	5,840
V	1,326	955	1,181	2,779	3,342
W	2,442	990	430	12,400	22,408
X	1,851	1,092	545	8,198	7,903

Table # 8 (continued) DESTINATION

ORIGIN	U	V	W	X
A	35	35	78	22
B	54	55	70	28
C	62	74	94	34
D	98	117	150	54
E	43	44	66	23
F	78	74	112	36
G	100	88	141	43
H	56	61	66	24
I	52	49	76	22
J	105	75	117	41
K	93	110	162	46
L	80	58	66	19
M	448	326	387	95
N	302	245	212	56
O	112	110	143	43
P	349	260	328	79
Q	848	391	357	104
R	1,516	934	424	141
S	204	220	526	95
T-	725	695	2,881	254
U	45,545	3,845	2,709	603
V	2,732	88,972	1,635	2,109
W	1,876	2,035	75,320	1,350
X	2,254	9,676	8,064	71,903

* See Report #3 relative to adjustment for Downtown Boston

STUDIES OF URBAN TRANSPORTATION

Table # 9

Seminar Research Bureau
Boston College

ORIGINS AND DESTINATIONS IN THE BOSTON REGION *
1959 Daily Work Person Trips
(One Direction Distribution By Travel Area)

ORIGIN	DESTINATION A	B	C	D	E	F
A	27,946	374	299	87	1,298	195
B	20,633	12,022	3,885	789	6,362	1,819
C	6,964	1,288	49,053	5,074	1,662	1,158
D	5,204	670	8,066	27,596	855	525
E	16,800	2,316	1,137	283	13,244	2,745
F	13,656	2,465	3,088	704	8,527	16,763
G	6,902	668	3,290	1,663	1,824	2,474
H	15,498	854	695	225	6,182	1,466
I	6,912	372	764	297	1,733	1,726
J	2,886	174	544	265	517	441
K	14,430	457	449	145	2,263	484
L	3,965	231	241	82	798	279
M	6,158	345	478	198	1,142	545
N	2,800	116	203	120	467	238
O	19,804	358	378	138	1,539	329
P	7,112	254	365	132	1,005	316
Q	2,163	97	130	52	338	128
R	1,984	61	95	52	307	140
S	28,228	727	847	252	2,665	580
T	16,750	421	569	192	1,321	332
U	3,400	143	249	90	454	130
V	3,053	128	353	98	353	115

Table # 9 (continued) DESTINATION

ORIGIN	G	H	I	J	K	L
A	64	1,580	62	47	1,345	155
B	289	2,493	134	129	1,094	331
C	588	954	137	175	458	152
D	735	648	123	224	355	128
E	307	6,065	233	133	1,490	394
F	1,572	5,747	1,025	454	1,325	601
G	10,508	2,378	1,048	1,336	790	474
H	375	25,803	821	257	4,359	1,6652
I	1,143	6,221	4,041	661	1,421	3,311
J	716	1,151	402	7,669	401	651
K	185	9,063	309	165	17,795	2,540
J	142	3,407	685	286	2,291	12,280
M	291	3,361	593	720	2,446	9,713
N	129	754	120	407	485	514
O	115	3,590	161	88	7,529	725
P	128	2,016	168	184	3,090	1,261
Q	56	605	73	104	670	445
R	66	481-	49	79	330	234
S	183	2,912	109	105	3,217	556
T	120	1,832	83	118	2,573	580
U	56	504	37	78	457	230
V	53	401	29	62	455	173
W	77	735	42	80	709	225
X	46	351	24	51	327	110

Table # 9 (continued)

ORIGIN	DESTINATION M	N	O	P	Q	R
A	210	63	870	41	36	29
B	495	105	421	53	63	36
C	296	78	193	33	40	26
D	342	149	175	31	47	35
E	556	153	599	73	80	62
F	1,253	314	551	99	130	108
G	1,024	291	323	67	93	89
H	1,681	250	1,135	129	126	78
I	3,152	312	523	99	134	71
J	1,970	636	142	58	107	55
K	2,352	258	3,522	387	260	98
L	11,095	348	568	197	238	94
M	31,577	1,789	806	392	886	379
N	2,419	23,477	210	118	329	307
O	1,023	174	14,407	433	214	82
P	2,280	457	2,248	7,269	1,789	333
Q	1,542	382	373	736	7,560	683
R	953	737	159	143	1,012	8,593
S	869	163	4,515	656	282	151
T	1,131	267	3,144	1,334	644	261
U	662	240	320	271	773	630
V	526	219	302	148	425	697
W	589	178	539	248	354	235
X	301	108	227	84	201	179

Table # 9 (continued)

ORIGIN	DESTINATION S	T	U	V	W	X
A	1,226	353	23	28	52	17
B	1,157	301	39	55	67	32
C	602	181	31	46	50	25
D	400	166	29	48	46	29
E	1,314	279	38	47	62	27
F	1,338	328	49	64	80	39
G	724	224	38	56	59	34
H	1,304	312	43	52	68	31
I	499	149	29	31	37	18
J	209	128	34	35	37	20
K	1,625	626	68	95	106	46
L	514	257	60	53	51	22
M	807	574	187	187	158	72
N	205	192	87	97	62	32
O	4,828	1,203	83	111	144	55
P	1,962	2,183	365	268	351	112
Q	448	616	324	218	155	81
R	310	350	368	355	122	85
S	16,818	4,895	193	232	484	120
T	6,780	21,882	411	508	1,317	238
U	704	1,412	5,907	1,552	718	396
V	597	1,072	894	24,397	607	1,536
W	1,516	4,503	487	876	8,414	744
X	522	838	265	1,608	825	9,250

* See Report #3 relative to adjustment for Downtown Boston

STUDIES OF URBAN TRANSPORTATION

Table # 10

Seminar Research Bureau
Boston College

ORIGINS AND DESTINATIONS IN THE BOSTON REGION *
1959 Daily Non-Work Person Trips
(One Direction Distribution By Travel Area)

ORIGIN	DESTINATION A	B	C	D	E	F
A	38,783	438	36	7	680	86
B	11,001	36,924	1,184	120	3,820	1,140
C	6,431	3,751	75,652	3,944	1,839	1,681
D	6,826	1,938	9,044	60,547	850	742
E	12,945	4,094	459	38	19,560	3,541
F	8,906	3,617	1,429	171	8,186	40,560
G	6,429	1,169	1,690	1,533	1,686	4,377
H	12,959	1,087	123	31	6,220	1,702
I	6,973	559	246	87	1,660	3,737
J	5,678	577	366	204	815	1,179
K	11,507	404	48	12	1,172	248
L	3,863	356	47	12	620	272
M	8,258	696	142	51	1,207	851
N	4,142	232	61	35	532	369
O	11,462	182	23	5	468	95
P	2,310	98	19	5	228	90
Q	2,434	156	26	10	286	140
R	4,106	155	33	15	474	284
S	17,846	441	77	18	960	194
T	12,059	298	61	16	481	126
U	4,248	220	66	18	375	116
V	4,263	227	76	25	317	114
W	10,273	380	97	28	582	176
X	9,754	468	145	48	616	218

Table # 10 (continued)

ORIGIN	DESTINATION G	H	I	J	K	L
A	11	709	31	2	726	20
B	57	731	43	4	293	34
C	378	529	111	27	233	30
D	1,130	454	160	54	273	34
E	92	4,495	161	13	795	68
F	1,131	3,888	1,182	73	612	111
G	32,042	1,858	2,003	519	581	160
H	123	35,909	1,196	39	4,045	575
I	1,385	8,013	20,427	376	1,647	3,374
J	1,548	1,940	1,616	20,888	724	711
K	38	5,945	267	16	37,671	877
L	62	3,554	2,396	103	4,604	21,656
M	217	4,085	1,807	453	5,099	17,613
N	96	863	260	201	721	403
O	12	1,114	65	3	4,981	102
P	14	456	63	12	1,570	217
Q	25	479	108	28	946	277
R	61	667	108	32	659	207
S	23	819	33	4	1,252	62
T	20	538	29	7	1,235	89
U	23	338	34	17	446	104
V	26	297	30	12	543	80
W	34	519	38	16	735	82
X	49	588	52	24	789	95

Table # 10 (continued) DESTINATION

ORIGIN	M	N	O	P	Q	R
A	15	1	1,180	32	1	—
B	31	210	24	2	—	—
C	36	1	188	31	1	—
D	75	17	259	44	7	—
E	55	5	593	54	5	—
F	158	15	439	78	11	1
G	225	29	398	83	14	2
H	282	15	1,405	129	16	—
I	1,252	36	843	163	29	1
J	1,689	386	382	212	57	7
K	461	11	7,001	638	36	2
L	16,223	58	1,215	701	94	7
M	58,334	783	2,180	2,016	846	87
N	2,080	42,844	506	441	208	112
O	89	4	33,911	581	21	1
P	294	19	2,209	25,286	458	12
Q	882	91	939	3,942	18,245	211
R	850	398	550	780	1,386	18,204
S	61	2	5,938	659	31	1
T	134	13	4,134	2,472	164	13
U	246	40	708	965	504	176
V	196	39	784	513	236	196
W	170	25	1,304	731	142	30
X	210	35	1,212	533	202	64

Table # 10 (continued)

ORIGIN	DESTINATION S	T	U	V	W	X
A	1,268	147	—	—	6	—
B	642	66	2	—	4	—
C	615	83	3	1	9	—
D	558	114	5	3	14	—
E	1,013	89	4	1	6	—
F	951	99	6	3	9	—
G	822	115	8	3	11	—
H	1,137	142	5	1	7	—
I	492	82	4	1	7	—
J	452	158	16	6	18	1
K	1,638	426	6	3	15	—
L	734	263	13	3	13	—
M	1,575	838	83	28	83	3
N	383	249	40	15	29	1
O	5,139	1,114	7	3	17	—
P	1,970	2,367	46	8	55	1
Q	967	1,113	216	46	98	4
R	1,026	749	477	173	133	13
S	35,431	7,070	20	6	82	—
T	16,116	45,483	121	45	770	8
U	1,722	2,032	16,485	629	855	49
V	1,544	1,588	1,165	39,449	708	410
W	4,577	7,746	478	240	27,941	145
X	2,843	2,528	658	2,330	2,450	23,634

* See Report #3 relative to adjustment for Downtown Boston

STUDIES OF URBAN TRANSPORTATION

Table # 11

Seminar Research Bureau
Boston College

ORIGINS AND DESTINATIONS IN THE BOSTON REGION *
1980 Daily Work Person Trips (Alternative 1)
(One Direction Distribution By Travel Area)

DESTINATION

ORIGIN	A	B	C	D	E	F
A	24,458	357	289	88	1,148	236
B	19,282	11,541	4,070	843	5,926	1,890
C	8,066	1,681	48,420	5,337	2,281	1,579
D	9,933	1,377	13,490	41,053	1,778	1,188
E	14,151	2,250	1,396	349	11,505	2,807
F	16,163	2,554	3,258	826	8,101	17,654
G	12,852	991	4,129	2,161	2,942	3,558
H	17,448	938	639	221	5,043	1,254
I	9,276	578	868	342	2,562	2,338
J	7,508	463	964	467	1,615	1,087
K	11,660	467	616	162	2,279	625
L	6,234	250	328	103	833	387
M	12,684	536	772	262	1,616	831
N	6,424	229	430	190	909	434
O	14,714	516	535	139	1,521	402
P	9,590	403	430	128	904	369
Q	4,606	203	247	80	452	207
R	3,684	188	274	96	510	251
S	25,164	652	785	239	2,694	636
T	17,455	451	808	274	1,546	451
U	5,565	229	425	159	640	243
V	3,850	138	319	125	369	143
W	11,780	337	676	247	959	345
X	7,421	249	573	227	633	243

Table # 11 (continued)

ORIGIN	DESTINATION G	H	I	J	K	L
A	89	2,381	86	77	1,113	329
B	324	3,530	195	209	1,091	435
C	717	1,341	180	230	661	252
D	1,428	1,590	258	451	778	331
E	332	5,460	286	241	1,346	421
F	1,723	5,550	1,092	635	1,611	883
G	14,800	3,560	1,562	2,089	1,487	848
H	334	22,693	750	315	3,833	1,553
I	1,485	7,648	5,244	994	1,695	4,027
J	1,438	2,538	842	16,067	1,036	1,265
K	245	9,840	344	218	19,927	2,897
L	166	3,533	745	310	2,361	13,352
M	399	4,244	795	990	3,301	11,096
N	216	1,551	233	701	1,136	940
O	152	3,311	172	175	6,886	712
P	150	1,976	160	180	2,870	1,166
Q	94	961	100	145	1,028	629
R	117	867	89	137	750	411
S	212	2,752	153	168	3,156	562
T	187	2,221	136	188	2,798	677
U	115	930	68	123	836	381
V	66	586	40	79	532	217
W	157	1,173	97	152	1,280	384
X	124	828	69	151	781	278

Table # 11 (continued) DESTINATION

ORIGIN	M	N	O	P	Q	R
A	479	89	720	109	75	34
B	728	127	650	137	118	78
C	460	112	340	75	74	55
D	709	235	357	97	100	78
E	637	153	531	91	79	56
F	1,620	308	692	163	156	115
G	1,643	369	620	161	179	126
H	1,563	227	915	153	134	69
I	4,028	354	658	157	165	85
J	3,804	969	499	139	199	97
K	2,799	319	3,710	545	303	139
L	11,832	316	536	241	242	88
M	42,376	2,217	1,093	633	1,298	491
N	4,376	37,099	432	263	575	503
O	1,168	176	12,168	708	320	101
P	2,104	374	2,513	7,092	1,485	318
Q	2,184	480	685	1,066	10,110	839
R	1,682	1,137	359	325	1,595	12,558
S	1,135	182	3,933	760	516	250
T	1,579	301	3,060	1,777	1,307	503
U	1,003	376	575	488	1,193	894
V	672	271	357	235	495	780
W	1,078	296	805	461	565	340
X	812	252	502	227	439	342

Table # 11 (continued) DESTINATION

ORIGIN	S	T	U	V	W	X
A	1,036	285	31	33	61	22
B	1,033	282	48	53	64	28
C	669	286	48	67	72	34
D	727	371	74	105	106	52
E	1,164	253	38	42	57	23
F	1,468	391	67	71	92	36
G	1,058	402	78	81	104	43
H	1,037	261	49	58	57	24
I	744	234	42	45	58	22
J	594	272	66	61	69	37
K	2,126	708	82	104	136	46
L	474	242	60	51	48	19
M	1,219	814	256	252	212	87
N	486	331	170	187	120	51
O	4,247	1,022	102	106	126	43
P	1,821	1,675	300	246	276	78
Q	747	1,145	442	295	198	94
R	650	867	575	550	185	117
S	14,540	4,248	180	210	437	95
T	6,738	24,200	488	595	1,524	239
U	6,970	1,997	9,089	2,280	1,030	508
V	619	1,138	986	25,516	650	1,490
W	2,206	6,552	736	1,340	12,757	992
X	1,133	1,782	539	2,965	1,876	14,542

* See Report #3 relative to adjustment for Downtown Boston

STUDIES OF URBAN TRANSPORTATION

Table # 12

Seminar Research Bureau
Boston College

ORIGINS AND DESTINATIONS IN THE BOSTON REGION *
1980 Daily Non-Work Person Trips
(One Direction Distribution By Travel Area)

	DESTINATION					
ORIGIN	A	B	C	D	E	F
A	42,357	521	58	14	1,028	196
B	11,886	47,594	1,886	209	4,443	1,542
C	8,082	6,480	107,006	6,361	3,355	3,122
D	13,386	5,008	17,790	130,261	2,176	2,115
E	11,492	5,138	782	84	21,469	4,845
F	14,197	5,141	2,437	345	10,624	58,630
G	15,669	2,378	3,062	2,982	3,798	8,374
H	16,873	1,600	150	47	6,070	1,721
I	11,282	1,257	418	158	3,390	6,649
J	18,021	2,036	868	521	3,930	4,169
K	8,011	433	85	20	1,341	428
L	8,653	508	99	31	853	564
M	24,744	1,593	368	107	2,357	1,848
N	10,636	566	192	75	1,230	802
O	7,363	318	52	11	519	153
P	3,952	237	39	9	244	131
Q	6,699	436	83	24	439	280
R	7,883	653	160	52	926	616
S	14,936	429	91	23	1,103	269
T	13,198	404	156	47	694	263
U	7,643	448	169	56	632	308
V	6,362	281	143	55	390	188
W	22,477	758	333	110	1,111	495
X	24,212	1,025	519	192	1,312	619

Table # 12 (continued)

ORIGIN	DESTINATION G	H	I	J	K	L
A	31	2,329	88	14	966	116
B	93	1,667	103	22	403	68
C	659	1,056	208	53	496	76
D	3,169	1,482	458	162	795	137
E	151	5,095	281	41	906	100
F	2,009	5,488	1,822	166	1,245	301
G	65,764	4,022	4,111	1,184	1,694	430
H	143	39,328	1,362	69	4,546	710
I	2,670	13,665	36,433	785	2,742	5,677
J	4,371	6,257	4,697	62,778	2,409	1,792
K	69	7,713	348	29	53,642	1,197
L	103	4,878	3,467	166	6,590	32,367
M	432	7,175	3,355	940	9,299	27,306
N	204	2,212	647	515	2,191	906
O	23	1,203	83	14	5,275	119
P	23	587	75	16	1,848	251
Q	60	1,014	182	56	1,770	494
R	141	1,565	247	83	1,938	458
S	37	943	63	13	1,540	75
T	50	983	74	21	1,802	142
U	73	902	83	37	1,086	223
V	47	618	55	24	843	131
W	115	1,232	142	49	2,088	214
X	163	1,601	179	90	2,245	275

Table # 12 (continued)

ORIGIN	DESTINATION M	N	O	P	Q	R
A	100	8	1,768	189	15	2
B	76	5	604	106	12	1
C	96	11	572	106	16	2
D	221	44	752	202	28	6
E	95	10	702	92	12	2
F	369	32	1,052	209	30	8
G	549	65	1,339	312	55	13
H	354	22	1,471	192	24	3
I	2,340	71	1,589	354	59	8
J	4,428	838	2,419	650	159	24
K	674	28	9,539	1,074	66	8
L	24,305	89	1,598	1,124	158	14
M	112,780	1,719	4,579	4,707	2,299	220
N	4,694	99,318	1,504	1,298	572	286
O	127	7	34,656	1,073	52	2
P	335	25	3,683	30,132	520	20
Q	1,600	172	2,684	7,173	36,398	447
R	2,035	1,042	1,811	2,266	3,312	41,409
S	110	6	6,563	890	81	12
T	277	25	5,060	4,576	505	57
U	527	102	1,903	2,240	1,272	459
V	335	85	1,323	1,091	460	401
W	481	72	3,021	1,981	425	90
X	677	113	3,134	1,624	653	203

Table # 12 (continued) DESTINATION

ORIGIN	S	T	U	V	W	X
A	2,080	278	4	2	17	—
B	762	92	6	2	6	—
C	965	226	14	7	22	—
D	1,339	368	24	12	44	2
E	1,240	140	5	2	9	—
F	1,652	209	11	3	20	—
G	1,776	344	22	7	37	—
H	1,109	184	7	3	—	—
I	1,179	236	10	4	18	—
J	1,967	562	39	14	48	4
K	2,596	659	11	6	26	—
L	922	380	20	7	18	—
M	3,707	1,920	192	74	175	8
N	1,247	622	132	58	92	5
O	5,273	1,337	10	4	17	—
P	2,215	2,543	49	14	52	1
Q	2,835	3,481	406	96	159	10
R	3,527	3,294	941	384	239	24
S	38,116	8,565	24	10	89	—
T	21,447	67,506	237	100	1,357	15
U	3,199	3,843	36,456	1,565	1,679	95
V	2,160	2,204	1,746	63,456	985	619
W	10,194	15,856	1,140	695	62,563	358
X	7,065	6,121	1,715	6,711	6,188	57,361

* See Report #3 relative to adjustment for Downtown Boston

STUDIES OF URBAN TRANSPORTATION

Table # 13

Seminar Research Bureau
Boston College

ORIGINS AND DESTINATIONS IN THE BOSTON REGION *
1980 Daily Work Person Trips (Alternative 2)
(One Direction Distribution By Travel Area)

	DESTINATION					
ORIGIN	A	B	C	D	E	F
A	23,999	371	303	101	1,195	248
B	18,332	11,719	4,181	940	6,055	1,937
C	7,468	1,667	48,561	5,619	2,274	1,586
D	9,030	1,337	13,313	42,028	1,737	1,158
E	13,439	2,275	1,428	383	11,697	2,858
F	15,145	2,554	3,294	917	8,144	17,813
G	11,265	927	3,907	2,435	2,772	3,385
H	16,575	945	652	244	5,104	1,275
I	8,611	573	868	380	2,539	2,329
J	6,653	438	917	491	1,531	1,036
K	10,983	468	626	180	2,287	632
L	5,787	246	328	110	825	386
M	11,368	506	742	270	1,544	800
N	5,372	223	424	197	890	427
O	13,990	520	544	152	1,536	406
P	8,912	396	431	138	897	368
Q	3,962	185	231	78	415	188
R	3,332	179	267	103	494	246
S	23,999	661	806	264	2,745	653
T	16,342	449	816	293	1,546	455
U	4,725	205	390	157	581	222
V	3,486	132	313	132	357	136
W	10,833	329	672	261	942	341
X	6,853	244	569	240	627	241

Table # 13 (continued) DESTINATION

ORIGIN	G	H	I	J	K	L
A	109	2,475	91	91	1,159	347
B	394	3,618	202	243	1,119	451
C	853	1,339	183	263	663	254
D	1,666	1,555	252	498	761	328
E	398	5,571	297	282	1,377	432
F	2,019	5,603	1,121	736	1,629	901
G	17,063	3,366	1,508	2,259	1,407	812
H	398	23,021	768	364	3,897	1,592
I	1,710	7,616	5,275	1,156	1,691	4,061
J	1,620	2,422	812	17,168	987	1,220
K	292	9,886	349	253	20,077	2,943
L	194	3,509	746	355	2,347	13,422
M	454	4,086	776	1,090	3,189	11,026
N	254	1,521	230	754	1,118	933
O	184	3,356	178	204	6,988	731
P	174	1,962	160	209	2,856	1,175
Q	104	884	93	151	946	586
R	136	841	86	151	728	402
S	257	2,807	157	195	3,226	580
T	223	2,229	137	214	2,818	689
U	125	846	63	129	762	351
V	79	571	40	83	518	214
W	185	1,158	96	169	1,265	384
X	148	820	69	168	776	279

Table # 13 (continued) DESTINATION

ORIGIN	M	N	O	P	Q	R
A	533	97	746	116	102	37
B	800	136	663	143	151	81
C	495	113	336	76	88	57
D	743	233	348	95	118	78
E	693	160	540	95	100	58
F	1,748	316	698	167	194	118
G	1,670	354	584	152	203	122
H	1,684	237	926	160	166	74
I	4,254	360	654	160	203	89
J	3,876	950	471	135	230	94
K	2,977	329	3,728	556	378	146
L	12,174	321	529	243	296	90
M	44,074	2,148	1,047	611	1,551	479
N	4,757	37,169	422	262	682	509
O	1,267	183	12,310	726	402	105
P	2,258	378	2,491	7,139	1,865	327
Q	2,207	452	630	992	11,299	799
R	1,806	1,124	348	321	1,811	12,567
S	1,241	189	4,006	784	632	261
T	1,713	307	3,069	1,813	1,555	519
U	1,079	351	524	452	1,264	838
V	713	267	347	231	565	778
W	1,161	299	793	460	666	347
X	881	256	497	229	518	347

Table # 13 (continued) DESTINATION

ORIGIN	S	T	U	V	W	X
A	1,077	301	41	35	71	24
B	1,056	292	64	57	71	29
C	666	290	61	70	80	34
D	713	366	94	105	113	52
E	1,184	259	51	46	64	24
F	1,477	397	89	73	100	38
G	998	383	97	80	108	42
H	1,050	268	64	60	64	24
I	738	235	54	45	64	21
J	562	263	79	62	73	35
K	2,132	723	109	109	149	48
L	469	243	76	54	52	19
M	1,164	781	314	249	220	95
N	476	328	217	190	127	52
O	4,301	1,046	133	111	142	44
P	1,807	1,679	384	253	304	78
Q	690	1,079	521	281	200	90
R	627	851	705	553	198	116
S	14,817	4,372	243	224	490	98
T	6,749	24,427	650	617	1,698	236
U	880	1,840	10,760	2,153	1,052	475
V	601	1,120	1,266	25,595	691	1,483
W	2,169	6,508	984	1,368	13,367	1,004
X	1,121	1,787	714	3,031	1,967	14,635

* See Report #3 relative to adjustment for Downtown Boston

destination figures in the tables 7 to 13, the data is made available. However, the Bureau wishes to caution the user against improper analysis and presentation. Usually the more general and comprehensive surveys utilizing this data can easily follow normal traffic analysis procedures to insure that the data remains as a correct representation of the facts. But the utilization of this data for extremely localized and minor problems and projects can easily lend itself to unjustified interpretation of these results. Therefore, the Bureau re-emphasizes the importance of the statements of accuracy of the data, encourages the user to review any use of the data with the Bureau, and reserves the right to express itself if the data is misused or misrepresented.

Note on Accuracy of the Data

Other statements in the body of the report and in Appendix A. deal with the accuracy of this data. These are to the effect that there is no method available for determining with complete statistical assurance the exact accuracy of each of the figures. The only way of obtaining exact accuracy in this or any other origin and destination survey is to undertake a 100% sample of existing travel habits and 100% sample of future living and travel habits in 1980. Neither process is possible.

It can only be said of these figures and those of any other traffic survey that makes estimates of future conditions, that:

a. the data reflecting future conditions of travel can be no better than the accuracy of the population and employment estimates;

b. the accuracy of the data concerning origin and destina-

tions is conditioned by the assumptions or estimates that are necessary regarding car ownership, trip frequency, travel speeds and the availability of reasonable facilities;

c. the error inherent in the model equation may be magnified in regard to the estimated flow from any one community to another where these communities are far apart and are connected by very few daily trips; but,

d. the error is relatively small as to the estimated flow between two adjacent communities, where the magnitude of flow is large;

e. the inherent error could either compensate for or compound any errors due to miscalculation of 1980 population and job distribution;

f. the error undoubtably becomes relatively small as the individual origin and destination linkages become joined with others to form basic accumulated desire patterns and traffic flows on major highway and transit facilities. (See Report #3)

Tests of the Data

Most origin and destination studies of any type are checked by counts of traffic along "screenlines." The actual volumes counted crossing a screenline, which extends across a metropolitan area, are compared with the volumes that cross the screen line as estimated by the origin and destination study. The difference between the volumes at the various intersections and as a total, provides a measure of the validity of the survey.

Unfortunately in Metropolitan Boston there are no screen line volumes that are now reliable and available for purposes of comparison.

The only area where actual and estimated traffic volumes can be reliably compared is around Downtown Boston at the location of a Cordon Count. The total number of persons entering and leaving downtown Boston (defined as the area bounded by Massachusetts Avenue, the Charles River, Boston Harbor, and the Fort Point Channel), counted in 1954, was adjusted in the study to reflect 1960 conditions. The difference between that count and the calculations is no greater than 2%. The gravity model estimate indicated that almost 580,000 person-trips were made into the Downtown Area each day (that is, with destination in the Downtown Area) and the adjusted 1954 actual cordon count indicated that about 570,000 persons traveled into the Downtown Area per day. The difference, as can be seen, is not great.

CONCLUSION

Our conclusion is that the procedure described in this report is a good one. We have found it to be a relatively simple and inexpensive method of gathering the travel information on Metropolitan Boston which is essential to the formation of transportation decisions.

The data derived in this way provides a good, adequate basis for evaluating existing and proposed transportation facilities for the Metropolitan Area. However, figures such as these are valueless in themselves and will prove their worth if they are kept up to date and implemented by appropriate governmental agencies.

It is the recommendation of the Seminar Research Bureau of Boston College that the procedures enumerated and the data derived thereby be utilized on a continuing basis by a well-staffed and appropriately financed Metropolitan Planning Agency - which this area so desperately needs - and that the findings of the latter agency be implemented by the Department of Public Works of the Commonwealth, working in conjunction with the Planning Agency.

Appendix A

ACCURACY OF THE DATA

It is very important for the user of the data presented in this study to be aware of the limitations of accuracy of the figures reported. In general there are two sources of error in any quantitative study; first, the variation resulting from the sampling procedure; and second, the inaccuracy introduced by the assumptions or models used in projecting the results into the desired end product of the study. The sampling variation has already been explained,[1] but it is so important that it will be reviewed first as a basis for understanding the limitations associated with the gravity model used for estimating interzonal travel.

At the outset of the study, a general limit of plus or minus 10% was established as a satisfactory degree of accuracy based on a knowledge of the amount of variation known to exist in travel patterns both on day - to - day and even hour - to - hour changes. In addition, the amount of available information from other research into travel characteristics provided additional checks on the results of a sample survey. Accordingly, a random sample of 100 families in 10 zones was determined to be satisfactory for the acceptable degree of accuracy. This small sample had the added advantages of minimizing cost and maximizing control over the interviews. Finally, although the general limit was to be plus or minus 10%, it was realized that many of the finer breakdowns of the data would be subject to larger degrees of error from the sampling variation, for example, the non-home based trips had a relative variation of 27%.

1/ Studies of Urban Transportation. Travel in the Boston Region 1959 - 1980. Boston College, Seminar Research Bureau, January 1960. P. 16, P. 25ff.

For end-products, the sample data had to be projected to include estimates of various modes and purposes of travel for all of the zones for the years 1959 and 1980, as well as interzonal travel flows for both time periods. Thus, it was necessary to determine what assumptions or models would be used for these projections. In the present state of quantitative method, it is, of course, impossible to state a numerical coefficient to measure the degree of error associated with such projection. The error can only be evaluated in a qualitative manner. This appendix is primarily concerned with evaluating the accuracy of the interzonal travel because the earlier study clearly presented the assumptions and models behind the other projections.1/

The model used for projecting interzonal flows is the "Inter-Area Travel Formula" or "Gravity Model."2/ The number of trips to be distributed is the number estimated in the earlier study. In order to use the "Gravity Model," it is necessary to determine the correct exponent to be used; in this study it was known that an exponent different from earlier studies was to be determined because the time-distance data included consideration of terminal time as well as travel time. The method used was to minimize the total chi-square value between the data observed in the sample zones and the data estimated by the model. Since this was the first attempt with such a small sample, it is worthwhile to discuss the problems encountered in some detail.

To begin with, the small sample did not provide many cells of the matrix with observations, so some method of combination

1/ ibid. p. 55 ff.
2/ ibid. p. 12-13

of cells had to be chosen. The method was to combine all the observations in rings of 5 minute intervals around each zone. Even at this stage of the chi- square procedure, the results were still biased, as was then determined, by failure to include walking trips in the number of trips to be distributed. In the final determination of the exponent by the chi-square method, some variation remained; but for the majority of the zones, the chi-square value was not significant at the 95% level, so the exponent was unbiased. The zone to zone errors were of course larger than the general degree of accuracy specified above, but this was to be expected. The errors in sample rings were larger than was desired, but since these errors were random, the exponent was acceptable. Finally, the data were tested against available screen line data, and the error was within the 10% limit.

It is impossible to state the degree of accuracy in the zone-to-zone figures resulting from the model. Without any qualification, it is large. (The error in larger origin and destination surveys is also very large on a zone-to-zone basis.) By a process of aggregation, however, the error is reduced step-by-step because the errors are random. In fact when a screen line or check point level of aggregation is reached, the general 10% error limit is attained. Of course, the data for 1980 are projected with additional assumptions, but are, nevertheless, as reasonable as possible, when used in the aggregate.

As the user must realize, every precaution has been taken to insure that no unrecognized error has crept into the projections. It is hoped that the user will take the same care to see that the conclusions drawn will not exceed the inherent inaccuracy of the sample and its projection.

Appendix B

Use of the Chi-Souare

Basically, the chi-square test is nothing more than a means of determining whether the amount of variation between observed (or actual) results and expected results is due to chance factors. In our case, it was used to determine the accuracy of the estimated numbers and destinations of trips, compared to the actual numbers and destinations observed in the home-to-home interview survey.

The test consists in finding the square of the variation of each actual result from the corresponding estimated result, dividing each squared difference by the estimated result and summing these relatives for each class of observations. This sum is known as chi-square (X^2) and may be expressed in symbols as follows:

$$X^2 = \sum \frac{(f_a - f_e)^2}{f_e}$$

where f_a = the actual result

f_e = the expected result

It can be seen that if $(f_a - f_e$ is zero in every comparison, the actual and estimated results would be the same, and X^2 would have a value of zero. If the differences are large, X^2 is large, denoting a poor correspondence between actual and estimated results. Conversely, if the differences are small, the value of X^2 is small, denoting a satisfactory correspondence.

However, the value of X^2 has no meaning until related to two other factors: the number of observations, and the confidence level desired. Thus, resort must be had to a table of X^2 values. The value of X^2 derived from the formula above is compared with

the value set out in the table for the appropriate number of "degrees of freedom" (which is one less than the number of classifications) and the desired confidence level.

T13 Boston College Seminar Re- c.1
B 1 search Bureau

~~Studies of Urban Transportation~~ ch
Travel in the Boston Region. Vol II.

DATE | ISSUED TO